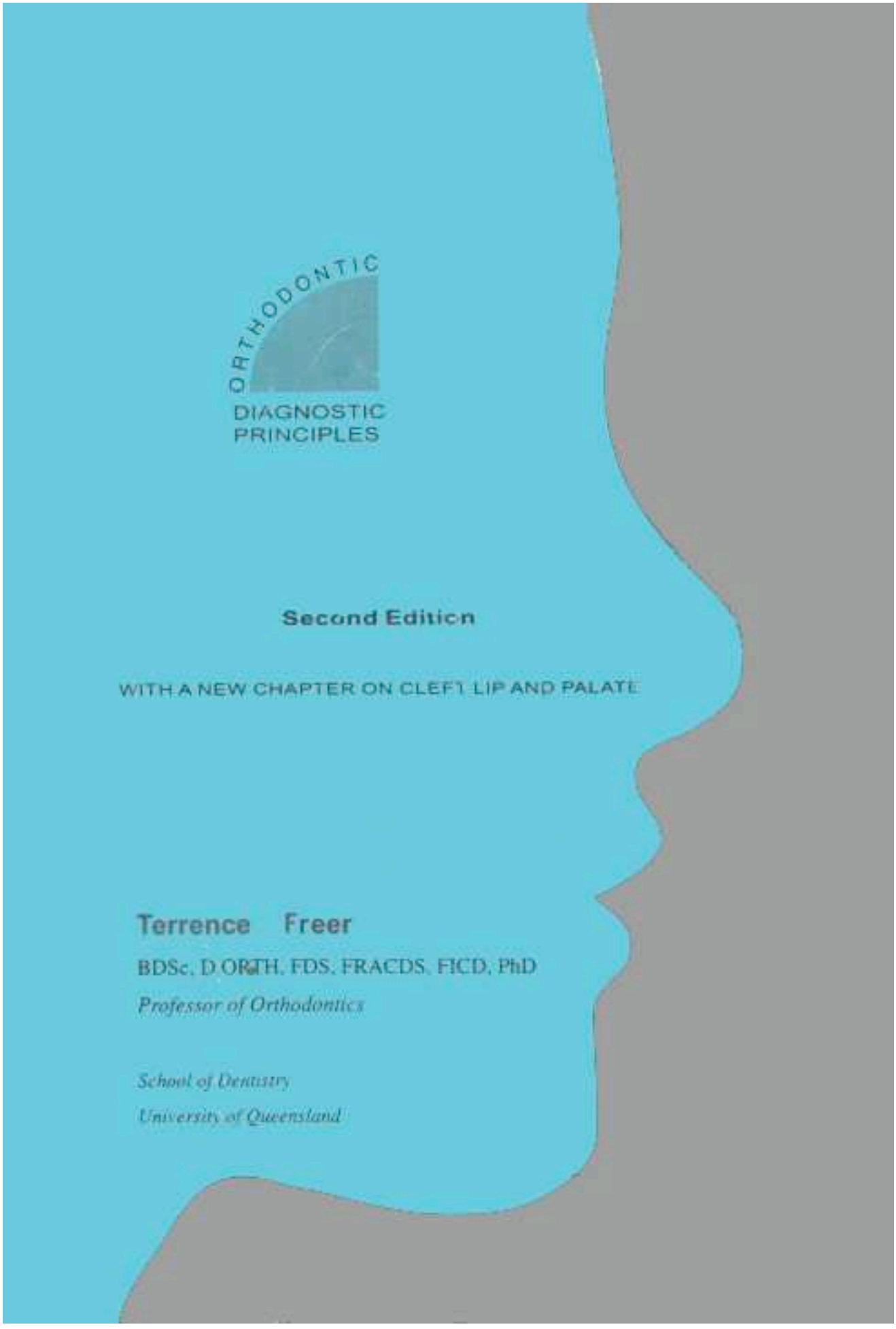


ORTHODONTIC DIAGNOSTIC PRINCIPLES

Second Edition

WITH A NEW CHAPTER ON CLEFT LIP AND PALATE

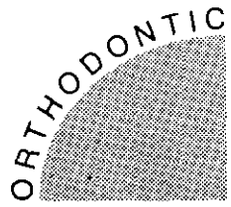
Terrence Freer

BDSc, D ORTH, FDS, FRACDS, FICD, PhD

Professor of Orthodontics

School of Dentistry

University of Queensland



DIAGNOSTIC PRINCIPLES

Second Edition

WITH A NEW CHAPTER ON CLEFT LIP AND PALATE

by

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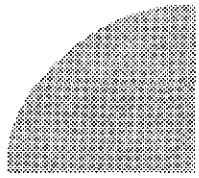
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Preface to Second Edition

A second edition provides a further opportunity to thank all those involved with the production of the first edition. A second edition also suggests at least modest success with the first edition.

Kira Hogg proposed the simple but effective design of the book and belatedly I would like to thank her for her contribution. She also laboured for many hours in reproducing the excellent line drawings in the book. The same layout has been preserved in this edition. We have maintained the objective of producing a book within the financial grasp of the average undergraduate dental student.

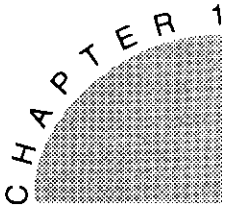
I would like to acknowledge the efforts of Mrs Linda Perry who gave her time freely in attending to innumerable details in producing the first and second editions and Mr Ian Taylor of the University of Queensland Printery for his unstinted time and advice.

This edition includes a welcome new chapter on Cleft Lip and Palate and I would like to thank my colleagues, Chris Ho, Steve Atkin, Rod Auer and Hugh McCallum from the Children's Oral Health Service of the Queensland Department of Health. They dedicate a significant proportion of their working time to the orthodontic management of craniofacial anomalies and contribute significantly to the education of undergraduate and postgraduate students.

The second edition also provides an opportunity to correct some flaws in the first edition. Feedback from a variety of orthodontic teachers and students encourages me to be bold enough to suggest that major alterations of the content are not yet necessary although given unlimited time and money, production improvements could be implemented.

I wish to express my sincere gratitude to Erica Maddock who prepared this second edition for publication. Her efficiency is of such a high order that it was difficult to keep up with her.

Finally I would like to dedicate this book to Anthony, a young patient of 12 years whose dog and appliance appear on page 174. He was afflicted with a severe congenital cardiac disorder and unfortunately is no longer with us. He was always cheerful and ready for a joke. He should remind all of us that in the hurly-burly of practice we can lose sight of the wood for the trees or more correctly we can lose sight of the patient for the teeth.



INTRODUCTION

Orthodontics is that branch of dental science concerned with the study and treatment of dento-skeletal anomalies associated with the growth, development and function of the dento-facial tissues and structures. The ultimate objective of most orthodontic treatment is an occlusion which functions normally, maintains oral health and enhances facial appearance.

Normal occlusion is a variable concept rather than a rigidly defined state. An occlusion which functions comfortably, has an acceptable appearance, does not require undue maintenance and does not jeopardise oral health may be regarded as normal. As a conceptual starting point it is easier to define ideal occlusion. However, many occlusions which depart from the definition of ideal may still be regarded as normal.

Clinicians are required to make treatment recommendations based on their experience, knowledge and the patient's preferences. The general practitioner must employ considerable skill in assessing the needs of every patient. Competent assessment requires an understanding of the patient's background and aspirations. The dentist is usually familiar with the patient's medical and dental histories and how they might influence compliance. Orthodontic treatment need is sometimes modified by more pressing personal or socio-economic factors. The practitioner must make a decision, in consultation with the patient, whether to provide treatment personally, refer for specialist service or recommend no treatment at all.

Assuming a competent diagnosis, the single most important factor determining the success of orthodontic treatment is patient cooperation. Few orthodontic treatment plans can succeed without it and experienced orthodontists devote considerable expertise to ensuring that the effects of poor compliance are minimised. Orthodontic treatment for the unwilling patient may be better postponed to a later time. Usually gingival inflammation and decalcification or caries are the direct consequences of poor oral hygiene. Additionally, non-compliant patients are often poor attenders so that orthodontic treatment becomes prolonged and in rare instances may even become unpleasant for both the patient and the clinician. With the widespread availability of orthodontic treatment, the need for compliance is underestimated or ignored by many patients. Where the primary decision to commence treatment is made by the parent, compliance by the patient is often below expectations. Where compliance is poor, the clinician may well judge that it would have been better not to have commenced treatment – a judgement usually made infallibly in hindsight.

Orthodontic Diagnostic Principles

The discipline of orthodontics presents a particular educational challenge in the undergraduate curriculum both in terms of content and the time set aside for orthodontic instruction. Competent orthodontic treatment relies upon competent case assessment and competent case assessment depends upon a broad understanding of the morphological and functional concepts of normality. The student must be taught to integrate knowledge from virtually every dental discipline in formulating a diagnosis and treatment plan. The objectives of treatment are related not only to the immediate orthodontic problem but also to those matters which impinge on treatment planning, including dental health status, cooperation and compliance, family support, geographical factors and cost. Because most orthodontic treatment is protracted the clinician is often, by default, expected to supervise management of the patient's oral health during the course of treatment.

The time available for orthodontics within the undergraduate curriculum is necessarily limited by the legitimate demands of other disciplines. Many critics of new graduates and even the graduates themselves do not always appreciate that there is keen competition by many disciplines for time in the curriculum. Furthermore, the content of the undergraduate curriculum has changed substantially in recent times with the full implementation of courses in gerodontology, dentistry for the handicapped, gnathology, implantology, infection control and others. All of these components have been added into the traditional mix so that demands on the student's time have become acute, particularly in the clinical years. Some members of the profession have suggested a period of pre-registration vocational training to ensure the maintenance of clinical standards.

The undergraduate orthodontic curriculum is usually directed to giving the student the ability to discriminate between simple and complex cases thereby encouraging the new graduate to restrict treatment to simple one dimensional objectives. The problem is that the treatment of virtually any orthodontic anomaly, even the simple one, may present difficulties which were completely unsuspected at the start and later require the implementation of strategies which may be outside the capabilities of the operator. For example, many texts use the single tooth anterior crossbite as an example of an anomaly which might be simply corrected by means of a removable appliance. However, this simple anomaly is often complicated by a lack of arch space, palatal displacement of the root apex or an underlying prognathic mandibular tendency which will become worse with skeletal development. What seemed to be a simple treatment problem may become a significant clinical and technical challenge. This example highlights the dilemma of the orthodontic teacher who strives to provide the undergraduate with a scientifically grounded methodology yet knows that often it may not be enough to enable the general dental practitioner to confidently predict clinical difficulties, responses or treatment outcomes.

Orthodontic teachers, and orthodontists in general, assume a cautious approach to diagnosis and treatment planning and this caution is often misinterpreted. However, the need for caution is substantiated by the present climate of increasing litigation and consumer advocacy. Additionally, the provision of orthodontic treatment is complicated by the concept of need to improve oral health or psycho-social status.

Much orthodontic treatment could be withheld with little impediment to the patient who may insist on treatment regardless of the assessment of minimal need by other persons. Yet a judgement of need is central to the provision of advice to the parent or patient.

Notwithstanding any of these issues, the traditional restorative treatment base of general practice has been modified by changes in disease patterns, wider access to public health systems and the contemporary social environment. Some practitioners have responded by doing more orthodontic treatment. Non-specialist orthodontic associations and groups have been formed to provide platforms for continuing education and to circumvent the cautious approach of orthodontists to the wider provision of treatment by general practitioners. Much attention has been directed to treatment by means of functional appliances which were claimed to promote optimal dento-skeletal development and minimisation of the need for extractions. There is little doubt that the debate has served to re-focus the attention of orthodontists on the benefits of functional appliances in properly selected cases. On the other hand, experienced orthodontists have rightly been sceptical of treatments which rely largely on the single concept of unqualified expansion of the dental arches. Neither does the available evidence support unequivocally the view that functional appliances promote significant sustained condylar growth, even when used at an optimal time. Long term research has underlined the need to follow cases for many years in order to assess the durability of treatment results and the evidence to date does not support any of the extravagant claims relating to skeletal growth modification.

Orthodontists have been in the vanguard of research into the effects of tooth movements on the facial profile. No other field of dentistry has so vigorously promoted the critical analysis of individual long term results. Orthodontic departments, societies and boards have encouraged analysis and comparison. The large number of orthodontic journals published around the world has ensured that there is widespread dissemination of research results. There is no orthodontic inquisition which promotes the proscription of unwelcome views. It is well recognised that on occasions, no orthodontic appliance will be capable of correcting the underlying abnormality. Orthognathic surgery in conjunction with orthodontic treatment may offer the most sensible approach. However, as with orthodontic treatment there is a tendency to believe that orthognathic surgery will always be successful. Such is not the case and relapse of surgical treatment continues to be a significant consideration. Many patients prefer the compromise result offered by orthodontic treatment alone, even when the possible advantages of surgery are explained.

The benefits of orthodontic treatment are clear to see in those cases which are treated competently and where there is a stark contrast between the pre-treatment and post-treatment conditions. However, studies show that a significant number of treatments fails to reach objectives, very often as a result of failure in cooperation. But even here the clinician must attempt to eliminate potential problems with adequate explanation of the patient's responsibilities and by ensuring that excessively ambitious treatment plans are not recommended for patients who have expressed a

resistance to certain types of treatment such as headgear. Relapse adds a further dimension to these difficulties. Relapse is a fact of life in orthodontics. Relapse is seldom complete but even partial relapse may be difficult to explain to the patient or parent.

This text aims to provide the undergraduate with a body of knowledge which will provide a simple basis for case analysis. It also seeks to provide explanations of some common localised conditions and to examine strategies which might be used in their resolution. These conditions may be unrelated to the broad classifications of malocclusion. A good example of one such condition is the impacted maxillary canine which if recognised early can often be successfully intercepted and the problem alleviated if not eliminated.

Orthodontics for the undergraduate has tended to concentrate on the broad picture determined largely by Angle's classification. While that classification will continue to form a framework on which to build, it does not satisfactorily classify the many local problems encountered day to day. This book for undergraduates is not intended to be a comprehensive reference source which discusses alternative theories and treatments. It is above all else a distillation of practical experiences based on current methodologies. Most particularly, this book is not a technical reference source intended to provide detailed analysis of the design and construction of removable or fixed appliances. However, chapters are devoted to a discussion of the common components of removable and fixed appliances.

No text can be expected to provide a comprehensive knowledge base for all clinical encounters. All new graduates must accept responsibility for extending their theoretical and clinical skills by means of continuing education throughout their professional career. As dental undergraduate courses move toward student centred learning, undergraduates will develop the skills required for continued learning and critical analysis. There seems little doubt that a significant number of general practitioners will continue to increase their orthodontic workload. The responsibility of orthodontic educators is to ensure that general practitioners are afforded access to various levels of continuing education with courses aimed at practitioners with different levels of experience. Responsible general practitioners should not go beyond their limitations in providing treatments for which they have had little training and should always recognise the consumer's rights to know of such limitations when consenting to treatment.

Finally, a word of caution. Much of the information traded back and forth as orthodontic philosophy has little inherent value. So often there are no means of substantiating new 'advances' other than by reliance on the persistence of the person who seems to believe what he or she is saying. The beginner will be eager to accept what appears to be plausible. Orthodontic history suggests that there are no grounds to ignore the available evidence in favour of modish solutions.

CHAPTER 2

POST-NATAL CRANIOFACIAL GROWTH

The head may conveniently be divided into two sections – neurocranium and viscerocranium. The neurocranium is that portion associated with neural structures including the brain, eyes and neural tissues. The viscerocranium is that portion associated with mastication, respiration and speech. The growth rate of the embryo is very high, as is growth of the neonate. However, the growth rate declines rapidly after birth and even during the puberal growth spurt, the rate does not approach these early high levels again. Post-natal studies have provided a wealth of information which forms the basis of our understanding of the growth processes although that understanding remains far from complete. The shape and proportions of craniofacial structures in the newborn are clearly different to those in the adult. Changes in proportion of the neurocranial and viscerocranial elements of the head reflect changes that occur with differential growth. The size of the neurocranium or brain case is largely dependent on the growth of the brain. Because growth of the brain is advanced at birth, the size of the neurocranium dominates the head of the infant. The viscerocranium is not nearly as advanced at birth (Fig.1) and at this stage the width of the face is greater than the depth and the height.

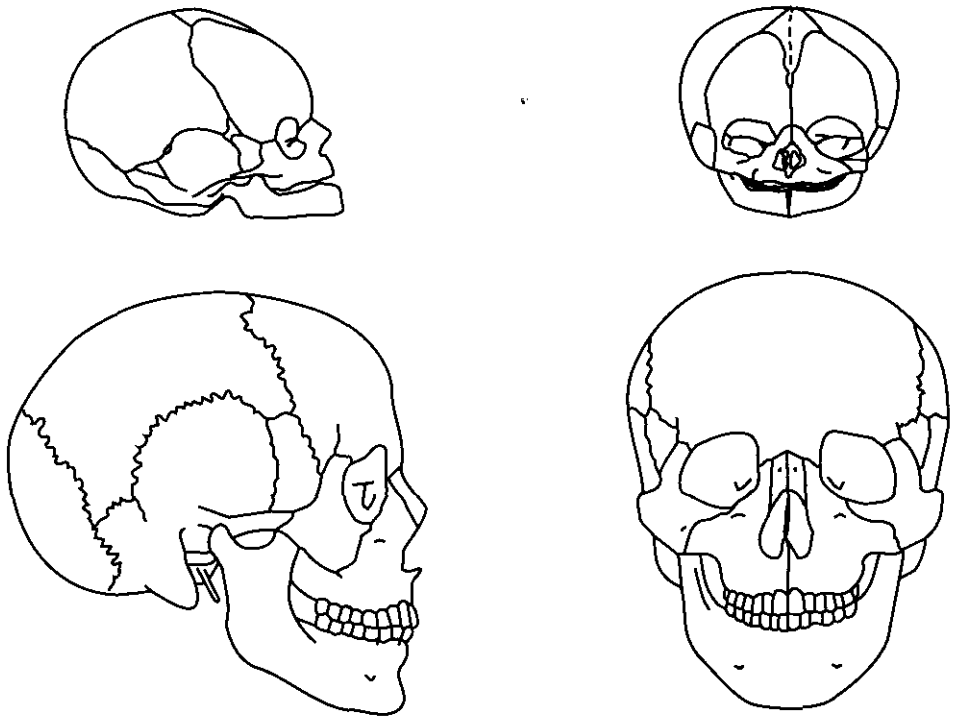


Fig. 1: Comparison of the relative sizes of the neurocranium and viscerocranium in the neonatal and adult skulls.

In the newborn the ratio of neurocranium to viscerocranium is about 7:1. During early post-natal growth both areas grow rapidly although by 5 years the neurocranium has achieved approximately 90% of the adult size while the viscerocranium has achieved only 45-50% of adult size. The viscerocranium continues to grow substantially until adulthood so that the final ratio of neurocranium to viscerocranium is about 2:1 or 3:1. The viscerocranium, during this period, does not grow equally in all dimensions. Growth increases in depth and height are greater than the increase in width. These differential increments are responsible for changes in the proportions of the face. (Nanda, 1992).

The major comparative differences between the neonatal and adult skulls are as follows:

1. The sizes and proportions of the components are markedly different.

2. There is little pneumatization of the bones of the head at birth and the sphenoidal, ethmoidal, frontal and maxillary sinuses have not developed.

3. Developing teeth literally fill the jaws. Teeth in the upper jaw lie in close proximity to the floor of the orbit.

4. Muscular processes of the various bones are undeveloped. The gonial angle, in particular, appears to be larger in the newborn. Development of the gonial angle as a muscular insertion for the masseter and internal pterygoid causes an apparent closing of the gonial angle.

5. The temporomandibular joint and associated structures are not completely developed. The articular eminence is small and the joint is little more than a saucer shaped depression.

6. The bony margins of the skull bones have not approximated in some areas and several fontanelles are still present at birth.

7. The frontal bone and mandible are separated at birth by the metopic suture and at the mandibular suture respectively. Both have fused by about the end of the second year.

8. Bones forming the base of the skull (cranial base), being endochondral bones, are separated by synchondroses which allow rapid post-natal adjustment. These include the basi-occipital, sphenoid, petrous temporal, ethmoid and frontal bones.

9. The nasal airway lies largely between the orbits whereas in the adult the nasal airway lies below the level of the orbits.

BONE GROWTH

There are two hasic types of bone formation — membranous and endochondral. Membranous bones do not involve an intermediate stage of cartilage formation. Membranous bones are found in the viscerocranium and the vault of the neurocranium. The only membranous bone outside the craniofacial skeleton is the clavicle. Endochondral bone formation depends on an intermediate cartilagenous structure which is replaced by bone during growth. The bones of the sensory capsule and the cranial base are of this type. The sphenoid and temporal bones are composites of endochondral and membranous segments. The mandible is a membranous bone which forms in close proximity to Meckel's cartilage of the first branchial arch but is not derived from it. The condylar cartilage is a secondary cartilage which is not histologically or physiologically equivalent to the epiphyseal cartilage of the long bone. The condylar cartilage is a dense fibrocartilage and is not capable of interstitial growth. For this reason the condylar cartilage is not usually regarded histologically as a primary cartilagenous growth centre, an issue of some importance in relation to treatments which purport to stimulate condylar growth.

Growth centres are often emphasised in development of the craniofacial skeleton. The synchondroses of the cranial base have received special emphasis because of their direct bearing on the growth of the inferiorly attached facial structures. The classical depressed middle third of the face in achondroplastic dwarfism is an expression of reduced endochondral hone formation and antero-posterior expansion in the cranial base and altered relationships between sectors of the skull and face. Sutures are not thought to be primary growth centres but rather adjustment sites which respond to expansionary forces from structures such as the brain. Emphasis of growth centres has tended to promote disregard of the importance of periosteal and endosteal apposition and resorption in bone growth and remodelling. Much of the increase in size and changes in proportions of the facial bones are accomplished by differential apposition and resorption leading to structural relocation and transformative growth, further influenced by muscular attachment and activity.

The current controversies concerning control of the growth processes and the effectiveness or otherwise of functional appliances in promoting growth, serve to highlight our fundamental ignorance of the governing processes in craniofacial growth. Phillips et al (1982) have demonstrated the profound effects of intracranial ablation of the trigeminal nucleus in two Macaca mulatta. Muscles on the deneverated side were profoundly atrophic and showed a significant reduction in mass. Histologically the muscles were more fibrotic and the muscle fibres were of smaller diameter compared to the other side. Morphological development of the affected side showed dramatic changes in the shape of the condyle, fossa and orbit compared to normal as well as changes in the occlusion. The authors were cautious in identifying the associated etiology but factors to be considered include sensory deficit, motor deficit, functional disturbance and elimination of neurotropic substances. They also note that the effects tend to be more pronounced in growing animals (Fig.2).

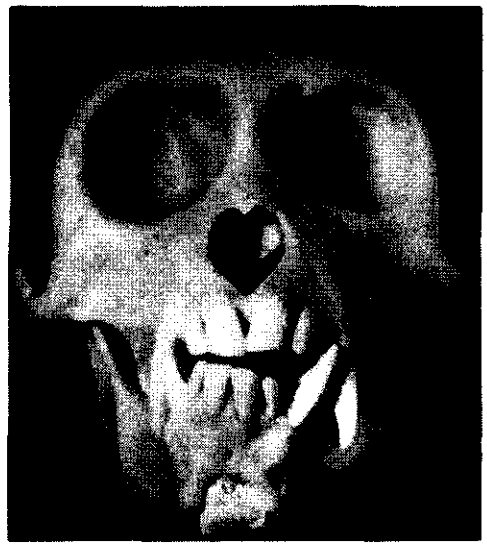


Fig. 2: Anterior view of a dry skull preparation 300 days post-operatively. There is a unilateral open-bite on the lesion side, while the maxilla and mandible are deviated to the control side. (From Phillips C, Shapiro PA and Luschei ES (1982): Morphologic alterations in Macaca mulatta following the destruction of the motor nucleus of the trigeminal nerve. Amer J Orthod 81: 292-8).

MECHANISM OF GROWTH

There has been a good deal of conjecture concerning the primary growth 'force' of the craniofacial complex. Scott (1954) has emphasised the importance of primary expansionary tissues such as the cartilage of the cranial base and nasal septum, the brain and the eyes, with the sutures playing a largely passive adjustment role. There is little doubt that the membranous calvarium responds directly to the growing brain and expansion of the cranial base. There would seem to be a high degree of independence, genetically determined, in the growth of the brain and the cranial base. Scott suggested that the cartilages of the cranial base, nasal capsule and Meckel's cartilage act as pacemakers in the early development of the facial skeleton.

Moss and Salentijn (1969) on the other hand, refuted the primary growth force theory of Scott. They proposed the functional matrix of the tissues, organs and spaces which, with optimum function, lead to optimum development with an interdependence of growth and function. Clearly the brain and eyes do not 'function' in the same manner as a muscular matrix and they have distinguished a capsular matrix, associated with calvarial growth and a periosteal matrix associated with muscular and osseous growth. They hypothesised that the bones of the face are not pushed apart by structures such as the nasal septum. Growth of bones within the periosteal matrices occurs in response to the demands of function. Thus, for example, the lower jaw does not grow in length as a result of primary condylar growth but is a response to global development of the jaw associated with continuing normal function of the surrounding tissue matrix.

While the functional matrix theory is supported by some observations of growth associated with disturbances in function, there is also evidence to support the primary force concept. In practice, normal development is probably dependent on a combination of both hypotheses. This means that normal growth and development will not be achieved in the absence of normal function, irrespective of the genetically determined potential of structures such as the brain, eyes and cranial base. Abnormal functional forces have a potential to direct growth abnormally but the critical and delicate balance between normal and abnormal function is not easy to identify. Much of the treatment philosophy involving functional appliances is based on an assumption that growth of the mandibular condylar cartilage can be re-directed if not stimulated.

The functional matrix theory is important because it suggests that early correction of abnormal function will lead to optimal growth and development. This further suggests that correction of some orthodontic anomalies ought to be undertaken well before the puberal growth spurt, after which stage growth tapers off. Note that the growth rate in the late mixed dentition phase is also relatively high compared with that in the puberal growth spurt.

CRANIAL BASE

The cranial base is an important growth adjustment site which joins the neurocranium to the viscerocranium. Most orthodontic attention has been directed to the midline cranial base but it should be recognised that the lateral cranial base is an important growth adjustment site in the pre-natal and immediate post-natal periods. Bones formed in the cranial base include the basi-occipital, petrous temporal, greater wing and body of the sphenoid, ethmoid and parts of the nasal septum. Ossification in the midline cranial base replaces cartilage so that a series of synchondroses are apparent (Fig.3).

At birth the basi-occipital, basi-sphenoid and pre-sphenoid ossification centres are well advanced and by 6 months the ethmoid ossification centre appears while the pre-sphenoid synchondrosis fuses. Thus in the young child the cranial base may grow in length at the spheno-occipital and spheno-ethmoidal synchondroses and at the junction between the ethmoid centre and frontal bone. By about 7 years only the spheno-occipital synchrondrosis remains open allowing growth of the posterior cranial base length until about sixteen years of age. The anterior cranial base from sella to foramen caecum stabilises by about 7 years and further growth in the anterior cranial base length occurs only by surface apposition at nasion and pneumatization of the frontal bone (Fig.4).

Achondroplasia is a developmental condition affecting the growth of cartilagenous bones. The effects are well illustrated in the skull where lack of development in the cartilagenous cranial base results in a failure of forward development of the mid-facial region compared with normal development of the mandible which is a membranous bone and therefore not affected by the condition. This leads to a severe maxillary retrusion (Fig.5).

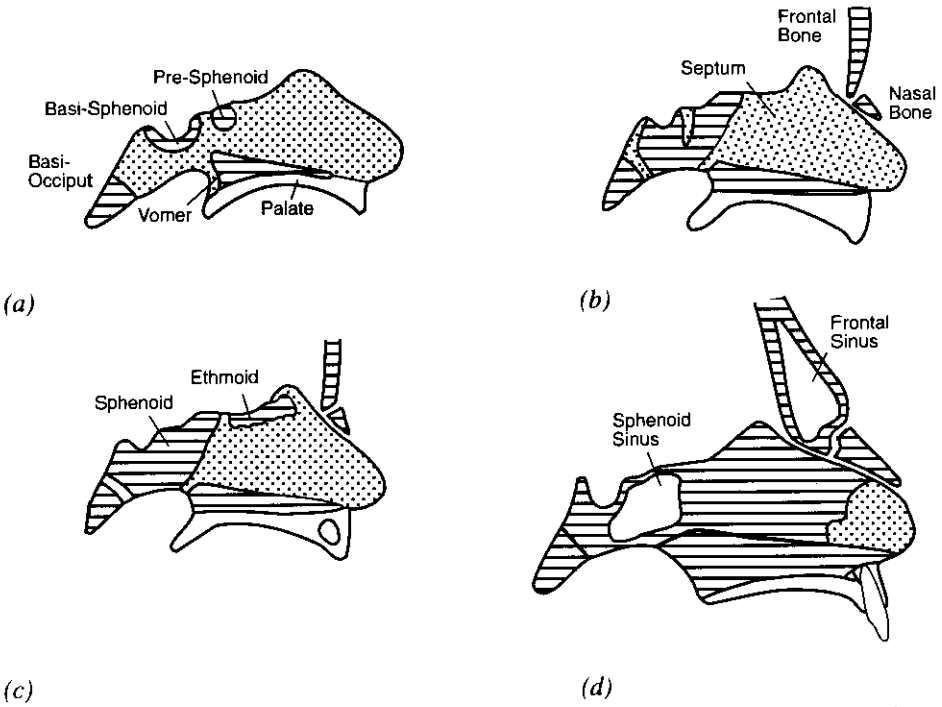


Fig. 3: Midline cranial base development commencing in cartilage in which ossification centres appear (a) foetal stage with the appearance of the basi-occipital, basi-sphenoid, pre-sphenoid, and vomerine ossification centres (b) at six months with fusion of the basi-sphenoid and pre-sphenoid centres (c) ethmoid centre appears at six months and continues to expand finally fusing with sphenoid at about seven years with the spheno-occipital synchondrosis being the sole remaining synchondrosis (d) adult cranial base with all synchondroses fused.

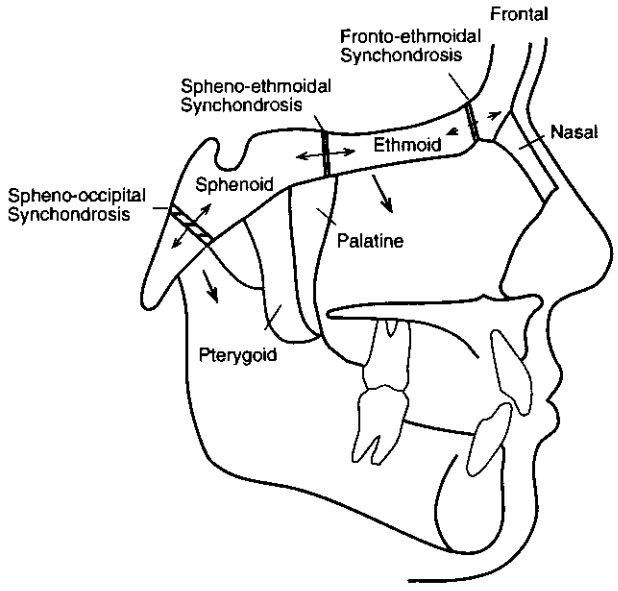


Fig. 4: Synchondroses in the cranial base.

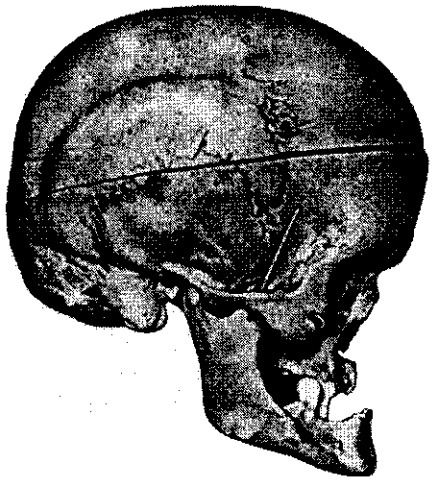


Fig. 5: Achondroplasia leading to under-development of the mid-facial area due to defective endochondral ossification in the cranial base.
(From Brash JC (1956): ***The Aetiology of Irregularity and Maloclusion of the Teeth)***

MAXILLA

Growth of the maxilla involves both expansion and translation. Expansion and relocation are associated with sutural growth and surface apposition and resorption. Translation is due in part to growth within the anterior cranial base which stabilises by 7 years and in part to the nasal septum which continues to expand. Hellman (1932) found that the whole facial skeleton swings outward from under the anterior cranial base so that the facial area becomes more prominent relative to the forehead. The greater part of this change occurs in the first seven years. The root of the nose moves least while the mandible moves most. Note also that active growth of the maxillae and associated bones is in a supero-posterior direction leading to the effect noted by Hellman.

The net effect may be represented as a downward and lateral migration of the maxillary complex relative to the cranial base with a general posterior growth expansion. In addition, there is a gradual appearance of the various sinuses and eruption of the teeth. Growth of the maxilla is coordinated with growth of the mandible. Growth in length of the dental arch occurs at the posterior tuberosity margins allowing for the development and eruption of successively more posterior teeth. While it is didactically useful to simplify the downward and forward growth of the maxillary complex, this may lead to misconceptions regarding localised changes which occur simultaneously. For example, the palate is progressively lowered by oral apposition and nasal resorption. This process leads to some lateral expansion as well, because of the expanding V principle.

Anterior resorption causes a relative posterior relocation of the anterior maxillary surface. The zygomatic process, increasing in size and by selective apposition and

resorption, both expands and migrates in a relatively more posterior and lateral direction. The principle of area relocation by means of selective apposition and resorption associated with the principle of V shaped expansion, accounts for marked changes in the shape of the facial bones quite separately from those migratory or translational changes associated with cranial base and sutural expansion. The build-up of muscular insertions with growth is largely the result of apposition, resorption and area relocation (Figs. 6 and 7).

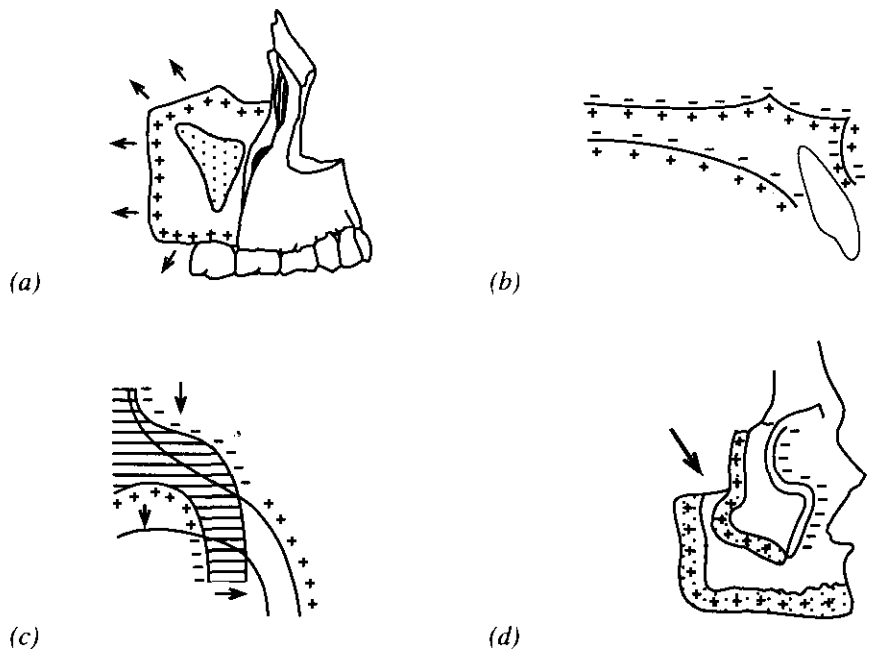


*Fig. 6(a) Maxilla grows posteriorly, laterally and inferiorly (b) palatal descent by apposition and resorption causing area relocation (c) relocation and transformation of the zygomatic arch posteriorly (d) malar process relocates posteriorly and maxilla moves away from the cranial base. (After Enlow DH : **Handbook of Facial Growth**. WB Saunders, Philadelphia, 1975)*

MANDIBLE

The mandible is attached to the lateral posterior cranial base by means of the joints, posterior to the spheno-occipital synchondrosis. Whether the condyles are true growth centres, they are the target of interceptive treatment which attempts to redirect their growth. The mandible grows in length posteriorly while area relocation and posterior V shaped expansion account for marked changes in structural features, thickness and shape. For example inter-ramus widths in the young child and the adult are in stark contrast as is the density and thickness of the bone. The posterior surface of the ramus is an important growth site and keeps pace with changes in the condyle region. The anterior border of the ramus is an area of net resorption coordinated with the posterior border apposition, leading to the increase in arch length for successive molar eruptions. Note again that this antero-posterior remodelling is accompanied by extensive area relocation and cortical drift (Fig.7).

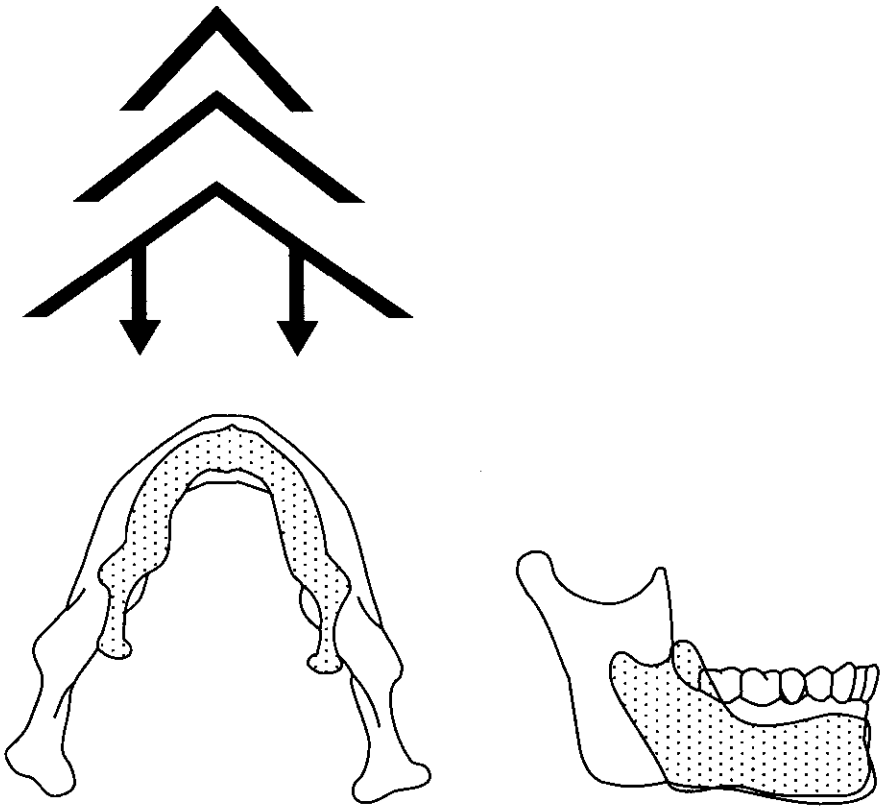


*Fig. 7: Growth and expansion of the mandible with area relocation and corical drift and following the expanding V principle of growth. '(After Enlow DH: **Handbook of Facial Growth**. WB Saunders, Philadelphia, 1975)*

However, this stylised concept of mandibular growth does not convey a true appreciation of the variations in direction of condylar growth that may occur. Bjork (1963) has shown that the net vector of condylar growth may vary widely depending on the underlying morphology of the mandible. While the overall net effect is a downward and forward growth of the mandible from under the skull, this simplification does not give sufficient emphasis to the variations that may occur.

Morphogenetic types play an important part in orthodontic treatment planning. The amounts of horizontal and vertical growth of the jaws are related to the underlying facial type. Treatment planning attempts to estimate the likely growth changes. This cannot be done accurately but major expected trends are reasonably well documented. Persons with square jaws tend to show a stronger horizontal component of growth while persons with excessive vertical dimensions tend to show stronger vertical growth. Cephalometric analysis provides an objective method of assessing facial morphology in treatment planning.

OVERVIEW

Growth of the craniofacial complex involves changes in size, shape and proportions. The neonate exhibits a small face with a large neurocranium. Brain growth at birth is advanced and largely completed by 5 years. Facial growth at birth is also rapid but continues until the end of the puberal growth period. The eyes of the very young child are relatively large because the eyes are basically neural structures which develop early. With development of the face, the relative size of the eyes decreases.

The ears of the infant appear to be low compared to the adult. As the viscerocranium develops, the ears do not lie as close to the lower border of the mandible and are therefore less prominent. Similarly, the bulbous prominent forehead of the infant 'recedes' with development of the viscerocranium.

The face of the young child appears unusually wide because of the early development of all width dimensions, particularly in the neurocranium. Interestingly, the eyes of the infant are almost as far apart as the eyes of the adult.

With continued growth, the nose descends from a position between the orbits in the infant to a position below the orbits in the adult. Growth of the nose is a particularly important factor in determining adult facial proportions. The nose of the neonate is always small and bears little relation to the final proportions of the nose in the adult face. Prediction of the extent of nasal growth is very difficult.

WORKING HYPOTHESIS

A description of the changes associated with growth is of little practical use if we are unable to incorporate those expected changes in a system of treatment planning. It is desirable to anticipate the changes due to growth as opposed to the changes due to treatment. Ricketts (1972) has proposed a growth analysis system which relies on cephalometric evaluation of the morphology of the individual.

Ricketts' system is based on the basion-nasion line representing the cranial base. He further postulated that, for practical purposes, growth of the craniofacial complex radiates along polar coordinates centred at the foramen rotundum in the postero-superior aspect of the pterygo-maxillary fissure, the point of emergence of the 5th nerve from the middle cranial fossa. We shall examine this method in more detail later. Some would disagree with its theoretical basis and accuracy. In spite of any shortcomings the method attempts to systematise the inter-relationships of growth and treatment and their effects on the appearance of the face. This systematisation promotes consistency of evaluation which is the essence of good treatment planning.

Because of the complexity of the growth processes, it is not possible to examine growth changes from a single superimposition structure. In order to evaluate the

local as well as the general changes, Ricketts proposed several superimposition positions, each of which examines specific changes in the craniofacial complex.

AGE

The concept of age is very important in orthodontics. We are concerned with three estimates of age: physiological, dental and chronological ages. Chronological or calender age is a familiar concept but may not be a useful indication of the state of bodily development.

Physiological age is a measure of the progress of the individual towards maturity. It is reflected in measures of height, bony ossification and the development of secondary sex characteristics such as breasts and puberal hair. Indeed, discussions of physiological age pay considerable attention to the puberal growth spurt. At that time, increments in various body dimensions, including those of the face, show acceleration to a peak level from which point growth increments subside to zero once adult proportions have been reached. Achievement of the peak puberal rate indicates that growth is now declining and orthodontic treatment will become more difficult, particularly where modification of dento-alveolar relationships is required in the more severe skeletal discrepancy cases.

Assessment of the state of physiological development may be undertaken in several ways:

1. Radiographic assessment of bone age, usually by means of a wrist x-ray and comparison with standards in a radiographic atlas. In particular, we note the state of epiphysial ossification of the phalanges, radius and presence of the adductor sesamoid (Fig.8).

2. The appearance of secondary sex characteristics including puberal hair, facial hair and broken voice (in the male), breasts and menarche (in the female). These begin to appear around the commencement of the puberal growth spurt but are not accurate indicators and menarche in particular may only signal that the peak velocity is past.

3. Careful plotting of stature and comparison with known population standards in the form of graphs. While not practical for most orthodontic purposes, it can help to define the period of peak velocity. Standard height curves and percentiles are available for comparison.

Physiological age standards are sex specific and females precede males. Females normally achieve peak velocity at approximately 11-13 years while males achieve peak velocity at approximately 14-16 years (Fig.9). Individual variation from the standards is common. As Tanner and Whitehouse (1982) have graphically demonstrated, individuals may vary considerably from the norms without being considered abnormal. In extreme cases, hormone therapy may be used to accelerate

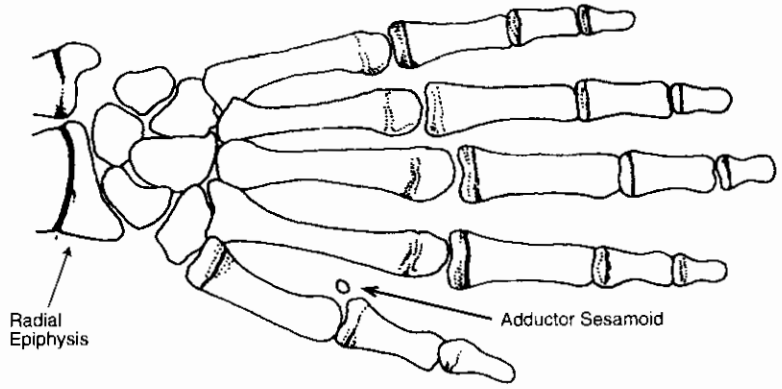


Fig. 8: Hand-wrist film tracing of a female aged twelve years. The adductor sesamoid has begun to ossify and the metacarpal epiphyses are beginning to fuse to the diaphyses.

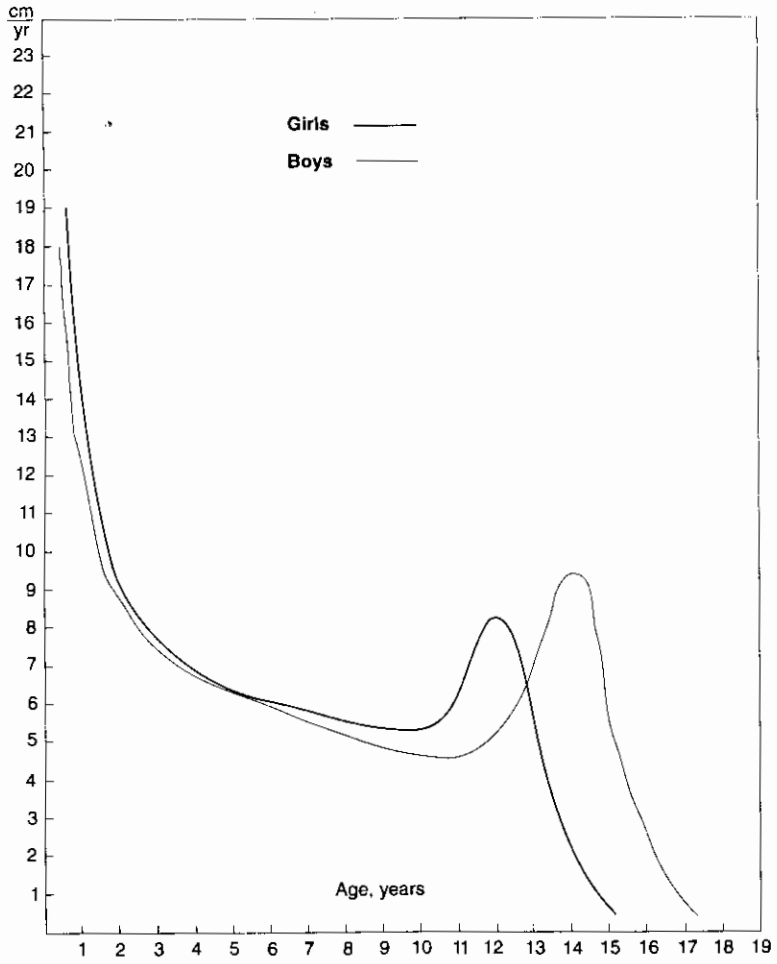


*Fig. 9: Velocity (increment) curves of height for normal males and females (From Tanner JM and Whitehouse RH: **Atlas of Children's Growth**. Academic Press, London, 1982)*

or retard development. Curiously, the effects of hormone therapy on dental age seem to be minimal although this point has not been thoroughly researched.

Dental age is the state of dental development compared with known age and sex standards. Once again, females tend to be ahead of males although the disparity is less marked. Practically, the importance of dental age lies in the fact that females may commence the puberal growth spurt before eruption of the canines and bicuspids, a dental stage which some practitioners mistakenly advise should occur before referral for orthodontic treatment. The later occurrence of the puberal growth spurt in males often peaks after eruption of canines and bicuspids.

Craniofacial proportions are approximately the same in girls and boys until about eleven years of age. The female facial form is complete soon after puberty at about fifteen or sixteen years of age. During the puberal growth spurt the facial differences become more pronounced quite apart from the appearance of facial hair. Facial growth in the male continues until about twenty years of age and is characterised by more pronounced growth of the nose and chin as well as a general increase in bulk compared to the female. The chin in the male may become quite pronounced due to increasing corpus length and symphysial development as well as the thickness of the overlying soft tissues. In females the supra-orbital ridges are less pronounced while the cheek bones are more pronounced.

Growth of the facial skeleton parallels that of the long bones, sharing in the adolescent growth spurt although some evidence would indicate a slight lag in facial growth. There is a significant correlation between the growth spurts in standing height and facial dimensions. The timing of the peak of the growth spurt and sexual maturation varies widely within and between the sexes. Menarche, for example may occur slightly before or after the peak growth spurt. Thus secondary sex characteristics are not totally reliable predictors of the progress of the growth spurt.

The puberal growth spurt is important for another reason. Because it is so closely associated with the commencement of sexual maturity, it signals a point of change in social activities which may be marked and may affect the patient's willingness to cooperate. In some instances there may be outright refusal to cooperate due to perceived peer group pressures and requirements. Most orthodontists would hope to commence treatment prior to the puberal growth spurt so as to gain maximum benefit from interceptive procedures where appropriate and to avoid the social difficulties which may become more salient at that time. However, other factors will often modify the starting time, such as the delayed exfoliation of deciduous teeth, a condition which tends to have a strong familial history.

More recent longitudinal growth studies have shown that small increases in various facial dimensions may occur after maturity. This is particularly true in males. Nanda and Ghosh (1995) documented significant increases in saggital facial dimensions between the ages of eighteen and twenty four years in both males and females. These changes may be of particular importance in the occurrence of late dental crowding and post-orthodontic relapse.

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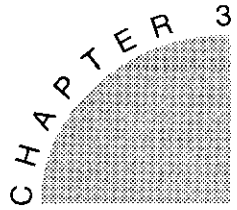
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RADIOGRAPHIC CEPHALOMETRY

Radiographic cephalometry was introduced by both Broadbent and Hofrath in 1931, working independently. It provides a method for objective measurement of craniofacial shape. To a limited extent, it may be used to assess some soft tissue structures such as the nose, lips, tongue and naso-pharyngeal airway. Both lateral and postero-anterior cephalograms may be taken. Most attention has been directed to the lateral cephalogram because the most noticeable differences between malocclusions occur in the vertical and antero-posterior dimensions. Note that the lateral cephalogram shows the antero-posterior and vertical dimensions. The postero-anterior cephalogram shows the medio-lateral and vertical dimensions and is useful in those cases exhibiting lateral skeletal discrepancies such as condylar growth dysplasia or crossbite. Both x-rays should be exposed with the head in exactly the same position if the same dimension is to be measured on the two x-rays. Ideally this is achieved by simultaneous exposure of both x-rays but very few cephalometers provide this facility.

The usefulness of cephalometrics as an aid to orthodontic diagnosis has been questioned. In particular, it is claimed that mean values should not be used to set treatment objectives for the individual patient because each patient presents a unique morphology and etiological background. This is an extreme view which denies the wealth of information and experience which has been derived from cephalometric research and analysis. Consistent treatment planning requires consistent pre-treatment analysis. While the undergraduate or non-specialist dentist may not study cephalometric theory in detail, some knowledge is desirable as an aid to understanding case analysis and goal setting in treatment planning. It is particularly useful in all cases with a skeletal discrepancy. Cephalometric analysis should be the rule rather than the exception for any patient exhibiting a skeletal discrepancy which contributes to a malocclusion. How else can the objectives of treatment be set in a quantifiable manner?

Cephalometric radiographs are obtained by means of high voltage radiation which maximises penetration and minimises exposure time. The practice of taking multiple interim cephalograms during treatment is no longer acceptable and all attempts must be made to reduce the number of cephalograms taken. In addition, effective radiographic hygiene procedures should be implemented. These include the use of sensitive film and intensifying screens, collimation of the x-ray beam to reduce tissue exposure, maximum beam quality consistent with the application, lead aprons and collars, quality assurance in processing and operator protection.

Cephalograms are usually exposed at a standardised target-object distance of 1524mm (5 feet) (Fig. 1). Unfortunately, no similarly standardised object-film distance has been adopted with the result that magnification rates vary between cephalometers. Thus, comparisons of x-rays taken on different cephalometers must account for different rates of magnification. For example, at a standard target object distance of 1524mm, when the object film distance is altered from 120mm to 160mm, the magnification increases from 8% to 11%. With a measurement such as the length of the mandible, (e.g. 120mm) there will be a substantial (3.6mm) difference between two cephalograms taken at different rates of magnification (Fig. 2). This problem can be overcome to some extent by the use of angular measurements and ratios which do not change significantly with changes in magnification.

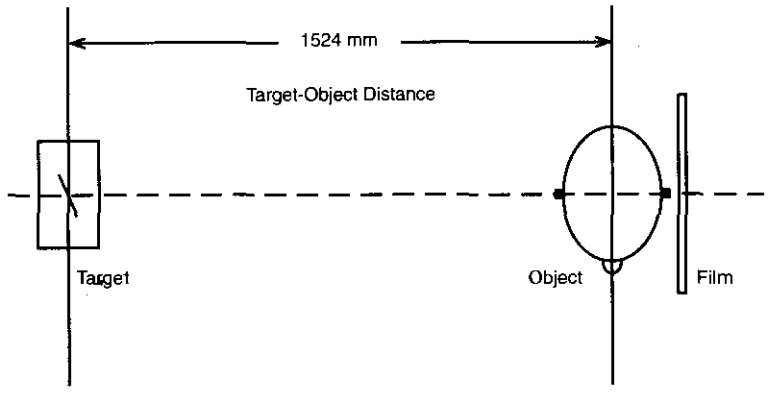


Fig. 1: A standard cephalometer set-up showing the target-saggital plane distance

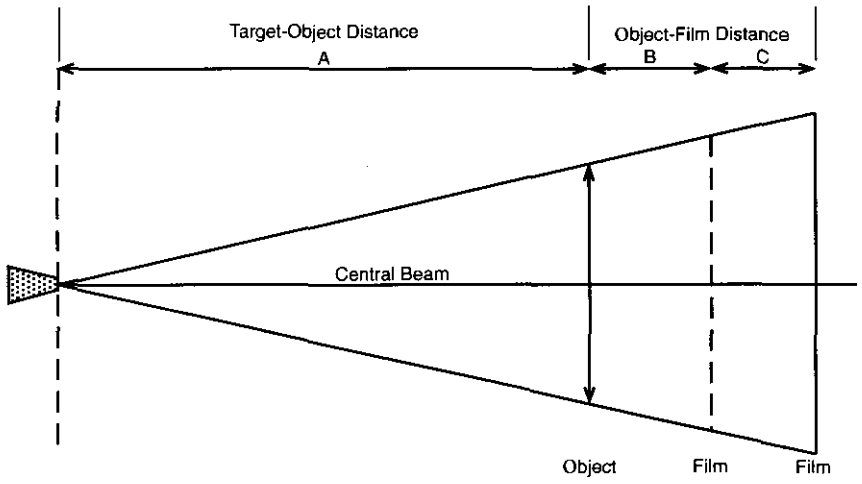


Fig. 2: Inter-relationships between x-ray source, object (patient) and film. Note, as the film is moved away from the object, the image will become more magnified. The ratio of magnification depends on the values of A, B and C.

If anatomical structures are bilateral such as the gonial angle, both sides should appear as separate images on the x-ray. This is usually due to unequal magnification of the right and left sides which are at different distances from the radiation source and the film. It may also indicate a true anatomical asymmetry. An adequate solution to the problem of double images is to trace both sides and estimate a mean of both images. However, distortion and magnification are substantial problems in cephalometry and every effort must be made to standardise the method of exposure as well as the definition and measurement of cephalometric variables used for analysis. Lateral cephalograms should be exposed and analysed with the patient's profile to the observer's right. In this case, the patient's right sided structures being further from the film will be magnified more than left sided structures.

CEPHALOMETRIC HARD-TISSUE POINTS

The simplified methodology used in this text is based on the methods of Ricketts (1972, 1979). All definitions assume the Frankfort plane to he horizontal and the pterygoid line to be vertical (Figs. 3 and 4).

Where anatomical structures are bilateral, both images are located and the average position between them is drawn and used to define the cephalometric point or structure.

Anterior Nasal Spine (ANS)

The most anterior projection of the palatal shadow. It is a saggital structure. The tip of the spine is relatively fragile and tends to be 'burnt out' making it difficult to locate. It defines the anterior end of the maxillary plane.

A Point (A)

The deepest point on the concavity of the bony surface anterior to the roots of the maxillary incisors. It represents the anterior limit of maxillary basal bone at the junction of basal and alveolar bone. It is subject to considerable alteration by orthopedic forces which tend to alter the position of the whole maxilla and by local movement of the upper incisor roots leading to bony recontouring.

B Point (B)

The deepest point on the concavity of the bony surface anterior to the roots of the lower incisors. It represents the anterior limit of the mandibular basal bone and lies at the junction of basal and alveolar bone. It may be altered by changes in the positions of the lower incisors.

Basion (Ba)

The lowest point on the anterior margin of foramen magnum in the saggital plane. It usually lies in close proximity to the apex of the odontoid peg of the second cervical vertebra. In the Ricketts system it defines the posterior end of the cranial base line from basion to nasion.

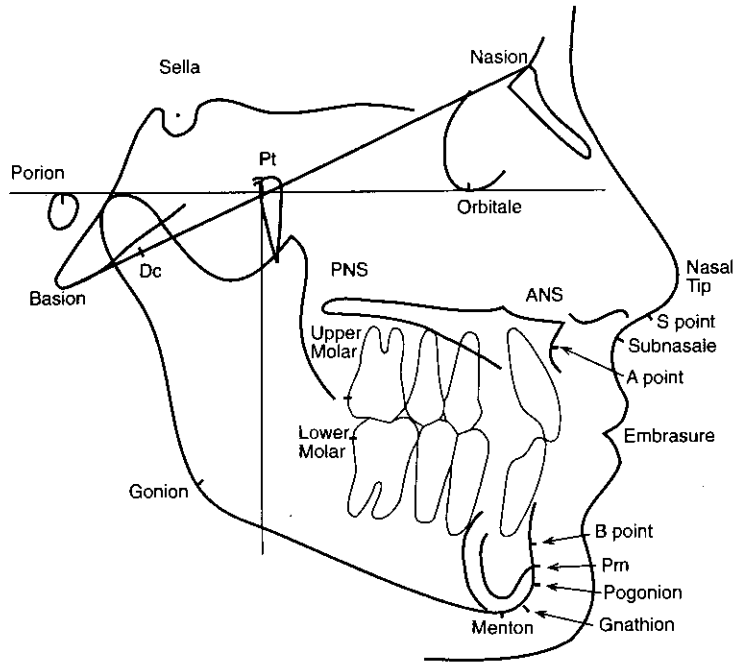


Fig. 3: Cephalometric points and structures.

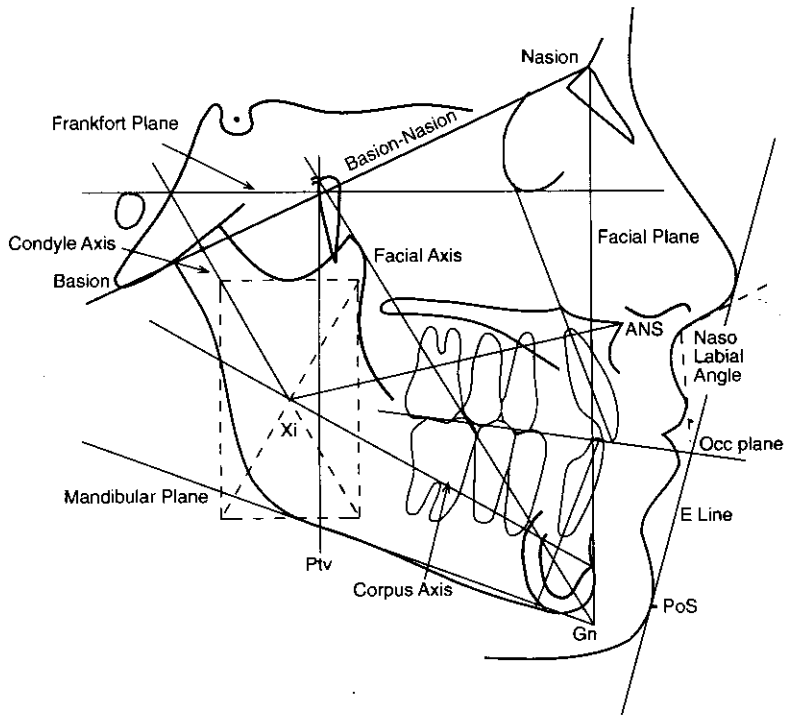


Fig. 4: Cephalometric lines and planes. Note that in practice the mandibular plane is often drawn as a tangent to the lower border rather than between gonion and menton.

CC Point (CC)
The intersection of the basion-nasion line and the facial axis. It is a superimposition point on the cranial base line (basion-nasion) from which downward and forward growth of the jaws is analysed.

Condyle Centre (Dc)
The centre of the condylar neck on the basion-nasion line. It defines the upper limit of the condyle axis drawn to Xi point.

Gnathion (Gn)
The lowest and most anterior point on the symphysial shadow. It may be located geometrically as that point at the intersection of the facial and mandibular planes.

Gonion (Go)
The lowest and most posterior point on the curvature of the gonial angle of the mandible. It may be located geometrically by constructing the posterior and lower border tangents to the mandible. The point at which the bisector of the angle, between these two tangents, crosses the gonial outline is the position of gonion.

Lower Molar Point (B6)
A point on the occlusal plane perpendicular to the distal surface of the crown of the lower first permanent molar (Fig. 8).

Menton (Me)
The lowest point on the outline of the symphysial shadow.

Nasion (Na)
The intersection of the inter-nasal and fronto-nasal sutures. It usually appears as a notch just above the maximum concavity of the fronto-nasal outline of the bony nasal bridge and may be difficult to locate without adequate illumination of the x-ray.

Orbitale (Or)
The lowest point on the infra-orbital marginal outline. It defines the anterior landmark of the Frankfort plane.

Pogonion (Po)
The most anterior point on the convexity of the symphysial shadow.

Porion (Por)
The most superior point on the shadow of the bony external auditory meatus. It defines the posterior landmark of the Frankfort plane. It does not coincide with the shadow of the cephalometer ear rod. The latter coincides with the soft tissue meatus and lies well below the bony meatus. The ear rod should not be used in the definition of Frankfort plane.

Posterior Nasal Spine (PNS)
The most posterior projection of the image of the hard palate and defines the posterior landmark of the maxillary plane.

Protuberance Menti (Pm)

The point on the anterior symphysial shadow below B point and above pogonion where the outline changes from concave to convex. It is the point of curvature reversal on the outline between B point and pogonion. It defines the anterior limit of the mandibular corpus axis.

Pterygoid Point (Pt)

Intersection of the inferior margin of the foramen rotundum and the posterior wall of the pterygo-maxillary fissure. It is located in practice as the most superior and posterior point on the outline of the pterygo-maxillary fissure.

Sella (Se)

The geometric centre of the lateral image of the sella turcica.

Upper Molar Point (A6)

A point on the occlusal plane perpendicular to the distal surface of the crown of the upper first permanent molar (Fig. 8).

Xi Point (Xi)

The geometric centre of the ramus of the mandible. It is defined by four points (R1, R2, R3, R4) and a parallelogram drawn through these four points with two sides parallel to Frankfort plane and two sides at right angles to Frankfort plane (Fig. 5). R1 is the deepest point on the anterior ramal curvature vertically between R3 and R4. R2 is the point on the posterior ramal outline at the same level as R1. R3 is the deepest point on the sigmoid notch curvature and R4 is the point on the inferior ramal outline directly below R3. Where double ramal shadows exist, these must first be averaged. Xi point is finally found by drawing the diagonals of the parallelogram and locating their intersection.

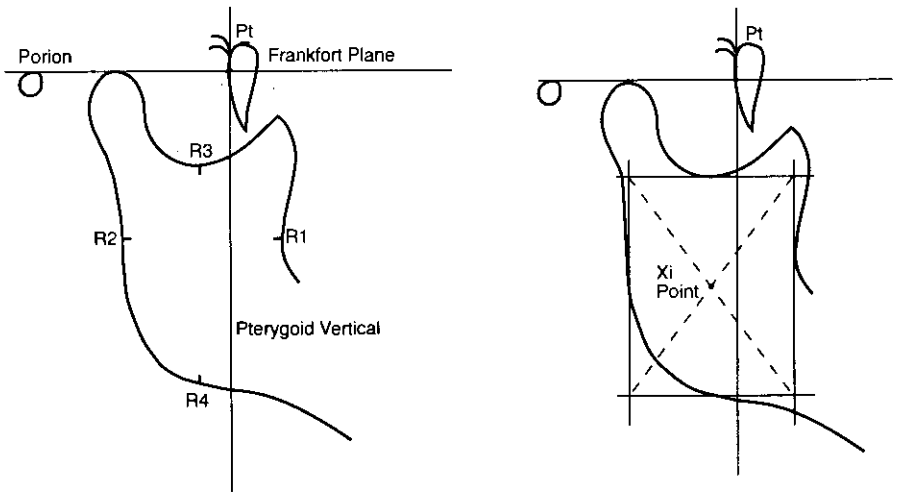


Fig. 5: Location of Xi point.

CEPHALOMETRIC SOFT-TISSUE POINTS

Embrasure (Em)
The point of intersection of the outlines of the upper and lower lips. Where the lips do not meet it may be taken as the point midway between the two lips (Fig.3).

Lower Lip Convexity (LL)
The most anterior point on the curvature of the lower lip measured relative to the Esthetic (E) line.

Nasal Tip (NT)
The point of contact of the E line drawn tangentially to the outline of the nose and the outline of the soft tissue of the chin.

Pogonion Soft (PoS)
The point of contact of the E line drawn tangent to the outline of the soft tissue of the chin and the nose.

S Point
The mid-point of the columella of the nose.

Subnasale (Sn)
The point of maximum concavity on the soft tissue outline between the nose and upper lip, lying closest to the anterior nasal spine. It is the point of reflection between the nose and the upper lip.

Upper Lip Convexity (UL)
The most anterior point on the curvature of the upper lip measured relative to the E line.

CEPHALOMETRIC LINES (LATERAL CEPHALOGRAM)

The term 'plane' is often used in cephalometrics whereas, in reality, a plane cannot be defined in two dimensions. The term plane has been retained where historical usage suggests its use, as in the case of Frankfort plane (Figs. 4, 6, 7, 8).

APo Line (APo)
A line joining A point and pogonion. It is used to assess the antero-posterior positions of the tips of the upper and lower central incisors. Where the upper and lower incisors lie too far in front of, or too far behind the line, there will be an associated effect on the prominence of the lips.

Basion-Nasion Line (Ba-Na)
The line joining basion and nasion and representing the cranial base junction between the neurocranium and viscerocranium. This line is used for superimposition centred at CC point.

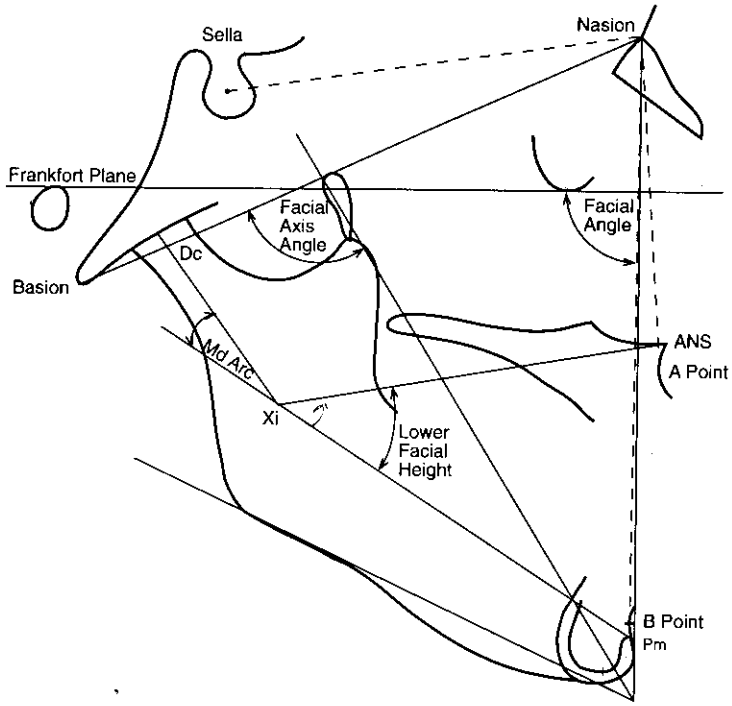


Fig. 6: Cephalometric angles

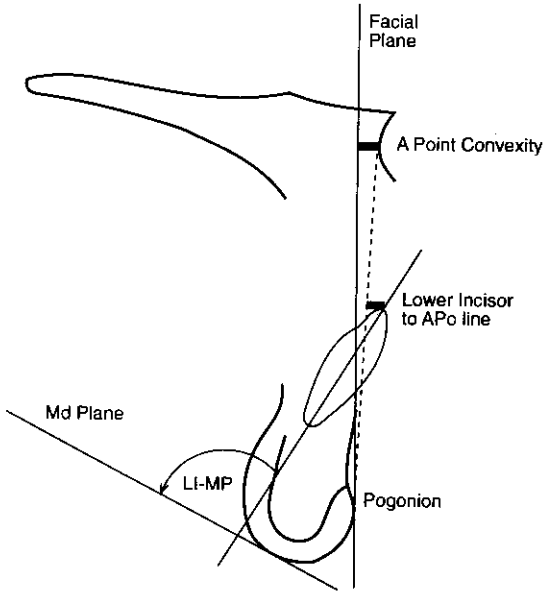


Fig. 7: Lower incisor and A point relationships

Condyle Axis (Dc-Xi)
The line joining the condyle centre and Xi point, being one of the lines defining the mandibular arc.

Corpus Axis (Xi-Pm)
The line joining Xi point and protuberance menti and defining the mandibular corpus. It is the other line defining the mandibular arc.

Esthetic Line (E line)
A line joining the nasal tip to the soft tissue pogonion.

Facial Axis (Pt-Gn)
The line joining pterygoid point and gnathion. It is an indicator of the direction of mandibular growth. In the absence of orthodontic treatment the mandible grows out along the facial axis and the angle changes little.

Facial Plane (Na-Po)
The line joining nasion and pogonion. The angle between the facial and Frankfort planes defines the position of the chin in space. The more retrusive the chin the smaller is the facial angle. The more protrusive the chin the greater is the facial angle.

Frankfort Plane (Por-Or)
The line joining porion and orbitale. It is one of the major reference and orientation lines in cephalometric analyses. It represents the natural postural head position with the patient looking straight ahead. While individual variations occur, the Frankfort plane is a relatively dependable indicator of the patient's natural upright posture of the head.

Lower Incisor Axis (LI)
The line joining the incisal edge and apex of the outline of the image of the lower central incisor.

Mandibular Plane (MP)
The line joining the menton and gonion. The mandibular plane angle between the mandibular and Frankfort planes is one of the most important determinants of facial morphology as used in cephalometric analyses.

Occlusal Plane (OP)
Two occlusal planes may be defined. The functional occlusal plane is the line of best fit, bisecting the buccal overbite from the first permanent molar forward to the premolars. It is the buccal line of occlusion and does not depend on the incisors. The importance of this definition is that it does not depend on the positions of the incisors which may be grossly anomalous where they have over-erupted into deep bite with a pronounced curve of Spee (Fig. 4).

Where the premolars are not shown we can only draw the occlusal plane from the mid-point of the overbite of the first permanent molars to the mid-point of the overbite of the incisors (Fig. 8).

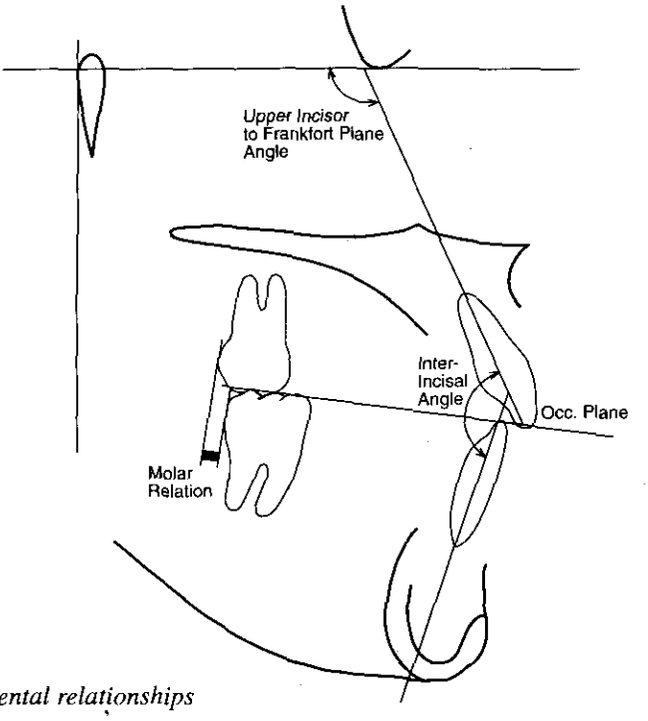


Fig. 8: Dental relationships

Palatal Plane (PP)

The line joining anterior and posterior nasal spines. Also known as the maxillary plane.

Pterygoid Vertical (PtV)

A line drawn through pterygoid point and at right angles to Frankfort plane. It is the second line of orientation in the Ricketts analysis.

Sella Nasion Line (Se-Na)

A line joining sella and nasion. It represents the anterior cranial base and, therefore, after 7 years of age grows only by apposition at nasion. It may be used for the superimposition of serial cephalograms centred at sella.

Upper Incisor Axis (UI)

A line joining the incisal edge and apex of the outline of the image of the upper central incisor.

CEPHALOMETRIC ANGLES AND MEASUREMENTS

(The nomenclature SNA, SNB, ANB is very widely used, particularly in the spoken form, and is therefore retained as an alternative form).
(Average values are shown in square brackets).

A-Na-B (ANB) Angle [+2 deg.]

The difference between the angles S-N-A and S-N-B. It is a measure of the horizontal difference between maxillary and mandibular basal positions often termed the

skeletal base relationship (Riedel, 1952). While it is a useful general indicator of antero-posterior skeletal relationships its utility becomes diminished in cases where the SNA and SNB are both well outside the norms. More recent analyses have used other measures of skeletal discrepancy (Fig. 6).

A Point Convexity [+2mm]

The distance from A point measured at right angles to the facial plane. When A point lies behind the facial plane the measurement is negative and, when in front, the measurement is positive (Fig. 7).

Facial Angle [87 deg.]

The posterior angle defined by the Frankfort plane (Por-Or) and the facial plane (Na-Po). It is a measure of the horizontal position of the chin relative to the upper face (Fig. 6).

Facial Axis Angle [90 deg.]

The posterior angle defined by the points Ba-CC-Gn. It is the angle between the cranial base line (Ba-Na) and the facial axis (Pt-Gn). The larger the angle, the greater the expectation that the chin will grow more horizontally than vertically, and vice versa (Fig. 6).

Lower Facial Height Angle [45 deg.]

The angle defined by the points ANS-Xi-Pm. It measures the height of the lower facial area. The greater the angle the greater the expectation that the face will grow more vertically and vice versa. Note that a low angle is often associated with a high facial axis angle (Fig. 6).

Lower Incisor to APo (LI-APo) [+1mm]

The perpendicular distance from the incisal tip of the lower central incisor image to the APo line. If the incisor tip lies behind the line the value is negative, while if it lies in front of the line the value is positive. This an important cephalometric variable and plays a major part in determining treatment objectives (Fig. 7).

Lower Incisor to Mandibular Plane (LI-MP) [92 deg.]

The posterior angle defined by the intersection of the shadow of the lower central incisor (LI) and the mandibular plane. It is a measure of the angulation of the lower incisor (Fig. 7). It is noteworthy that in order to maintain normal relationships, the mandibular plane angle and the lower incisor to mandibular plane angle vary inversely. As the mandibular plane steepens, the LI-MP angle is expected to decrease by the same amount and when the mandibular plane angle decreases the LI-MP angle increases by the same amount.

Lower Lip to E line [-2mm]

The perpendicular distance between the lower lip convexity and E line. When the lower lip lies behind the line the value is negative and when the lower lip lies in front of the line the value is positive. Normally in the young patient the lip should lie just behind the line (Fig. 4).

Mandibular Arc [26 deg.]

The angle formed by the condyle axis and the mandibular corpus. It is the complement of the angle defined by the points Dc-Xi-Pm. A high mandibular arc angle is usually associated with a high facial axis angle and a low Frankfort-mandibular angle (Fig. 6).

Mandibular Plane Angle [28 deg.]

The angle between the Frankfort and mandibular planes and often termed FMA (Frankfort-Mandibular Angle). It is another measure of the vertical height of the face. A low angle is often associated with a high facial axis angle and vice versa. Low angle cases are brachyfacial. High angle cases are dolichofacial (Figs. 3 and 4).

Nasolabial Angle [115 deg.]

The angle formed by the lines joining upper lip convexity, subnasale and S point (the mid-point of the columella). It is an important measure of the shape of the nasolabial region. This angle is liable to increase as the upper incisors are retracted excessively.

Se-Na-A (SNA) [82 deg.]

The angle defined by the points sella-nasion-A point. It is a measure of the horizontal position of the maxilla relative to the cranial base (Fig. 6).

Se-Na-B (SNB) [80 deg.]

The angle defined by the points sella-nasion-B point. It is a measure of the horizontal position of the mandible relative to the cranial base (Fig. 6).

Upper Incisor to Frankfort Plane [109 deg.]

The angle between the long axis of the upper central incisor and the Frankfort plane. It is measured as the posterior angle between these two lines. It is an indicator of the proclination or retroclination of the upper incisor (Fig. 8).

Inter-Incisal Angle [130 deg.]

The posterior angle between the upper and lower incisor axes. It is a measure of the incisal relationship and may play an important part in determining the ultimate incisor overbite (Fig. 8).

Molar Relation [-3mm]

Measured from the distal surface of the lower molar to the distal surface of the upper molar along the occlusal plane. Because it is measured in a posterior direction it is recorded as a negative value (Fig. 8).

HORIZONTAL RELATIONSHIPS

Assessments in the horizontal plane are difficult to visualise with many of the standard cephalometric analyses. The nasion vertical (NaV) line is a line dropped from nasion at right angles to the Frankfort plane (Fig. 9). It has the advantage of

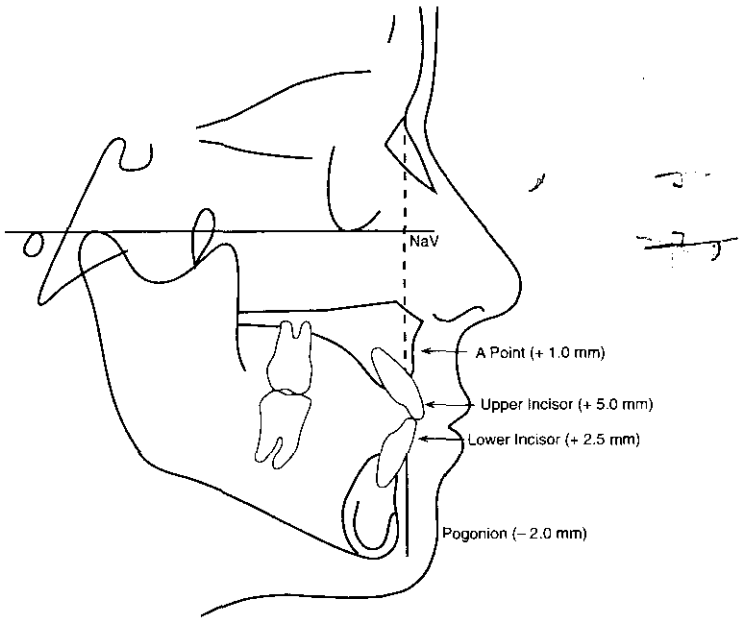


Fig. 9: Dental and skeletal norms relative to the nasion vertical (NaV).

being conceptually simple and practically useful. It was formally introduced by McNamara (1984). Because the Frankfort plane is a good indicator of the natural upright postural head position, the nasion vertical is a good indicator of the relative horizontal positions of the lips, teeth and chin.

Norms have been established as follows:

A point	+1.0 mm
Upper incisor tip	+5.0 mm
Lower incisor tip	+2.5 mm
Pogonion	-2.0 mm

Another very useful indicator of soft tissue relationships is the subnasale vertical (Legan and Burstone, 1980; Scheideman et al, 1980, Bell et al, 1986). Similar to the nasion vertical a line is drawn through subnasale at right angles to the natural horizontal plane. This method is of particular value in the assessment of surgical cases where the underlying skeletal pattern is abnormal by definition and therefore norms based on underlying skeletal structures are not very helpful. The method indicates the surgical skeletal corrections required to normalise overlying soft tissue relationships. As the underlying bones are moved the soft tissues covering them will move to more acceptable positions (Fig. 10).

Norms to SnV have been established as follows:

Upper lip convexity	+1.5 mm
Lower lip convexity	-0.5 mm
Pogonion (soft)	-4.0 mm

These same authors also advocated the use of simple proportional measurements in assessing the relative contributions of the vertical components of the upper and lower facial areas to facial proportions.

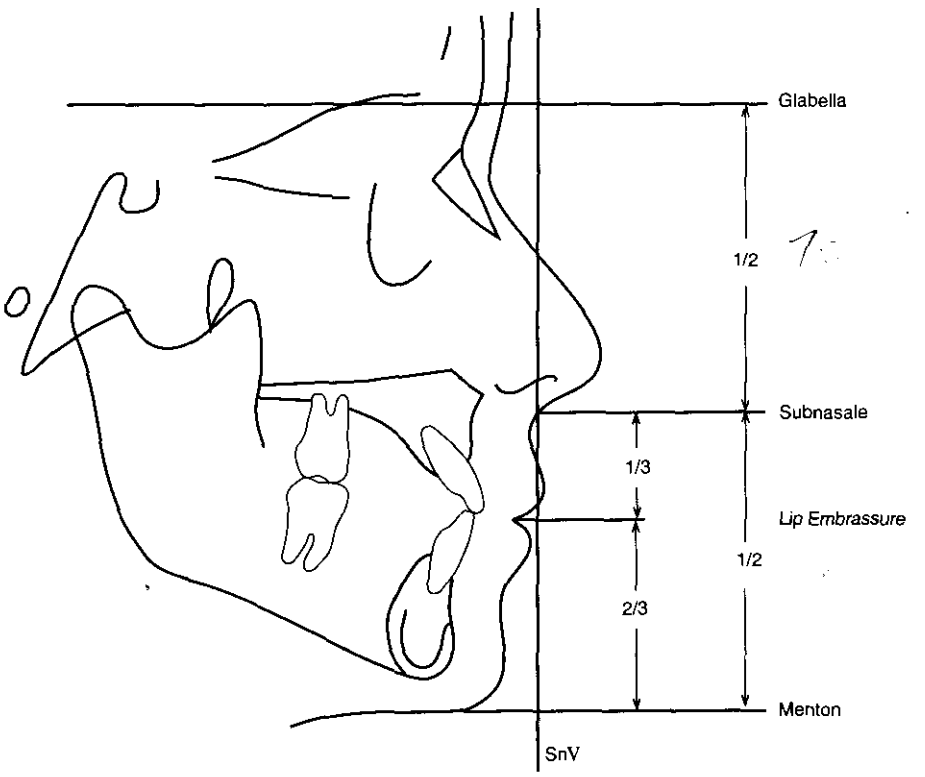


Fig. 10: Proportional assessment of the components of upper and lower face. Also shown is the subnasale vertical (SnV)

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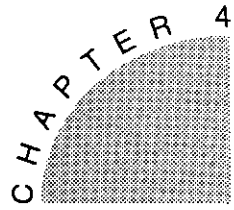
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CHARACTERISATION AND CHANGE

Cephalometric analysis provides one method for understanding dento-facial types. Modern methods of orthodontic analysis and treatment planning depend on a comprehension of morphological skeletal types and their general relationships to expected growth patterns. With this knowledge, the clinician will be in a stronger position to assess the available options in treatment planning. It is the process of comparative evaluation which is important in case assessment. Cephalometric analysis must be supplemented with careful clinical observation. Soft tissue contours do not necessarily correspond closely with the associated skeletal framework. Burstone (1958, 1959) established standards for normal soft tissue relationships. Orthodontic decisions must be based on an integration of the skeletal, dental and soft tissue assessments.

FACIAL PATTERNS

The method of facial analysis does not need to be complicated but should be consistent. Standardised photographs are helpful in this regard. Photographs should be taken at standardised focal lengths and apertures. The teeth should be lightly in habitual occlusion and the head should be oriented with the patient looking ahead at a point level with the line of sight, indicative of the natural head position. Variation in the tilt of the head will materially affect the retrusion or protrusion of the facial structures, particularly the chin. Where serial photographs are taken for the same patient, their comparability may be diminished by a failure to standardise the photographic method. This difficulty will be exacerbated where multiple operators, such as chairside attendants, are responsible for taking the photographs.

Various methods of evaluating facial proportions have been proposed usually based on norms derived from samples of subjects with balanced profiles and proportions. These norms provide a didactic starting point but it should be clearly recognised that individuals with quite severe malocclusions may show relatively balanced soft tissue proportions and conversely other individuals with facial proportions which do not fall within accepted parameters may exhibit quite normal or even ideal occlusions (Fig.1). Legan and Burstone (1980) pointed out that there is a relatively poor correlation between dento-skeletal patterns and overlying soft tissue relationships. The soft tissues exhibit a highly variable thickness which camouflages the positions of the bones and teeth. The lips may be more protrusive or retrusive than expected from the positions of the teeth. Nevertheless the clinician must try to minimise unwanted side effects of treatment on the soft tissues such as undue retraction of the lips if extractions are to be recommended. Providing treatment

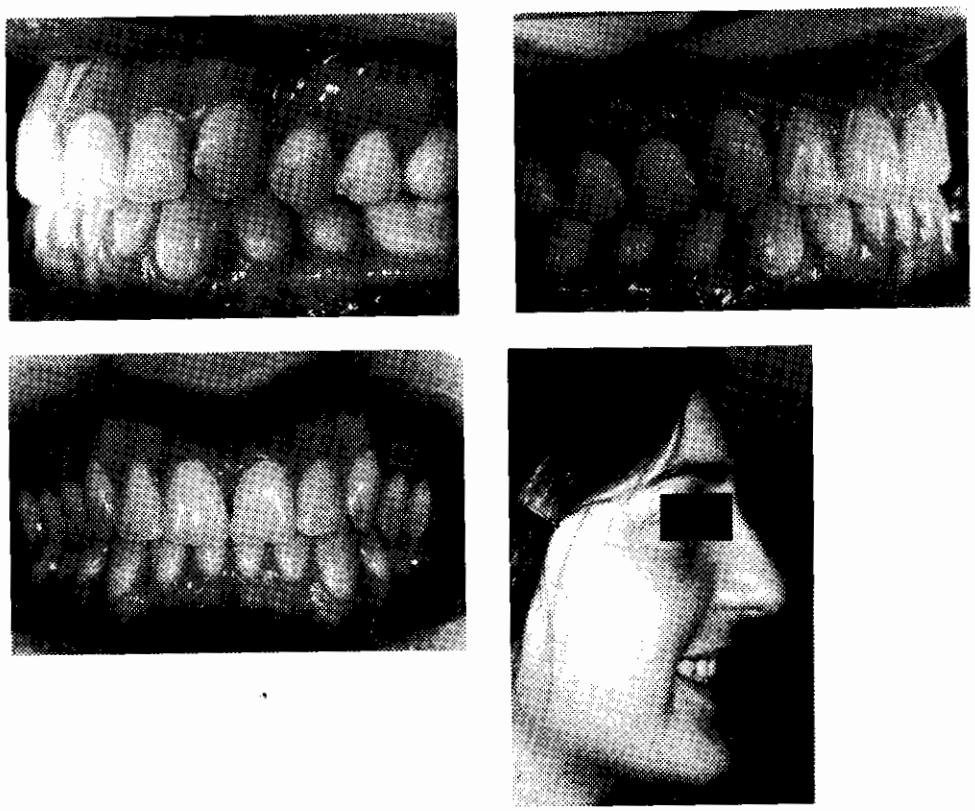


Fig. 1: Excellent occlusion associated with facial profile parameters which fall outside the expected values.

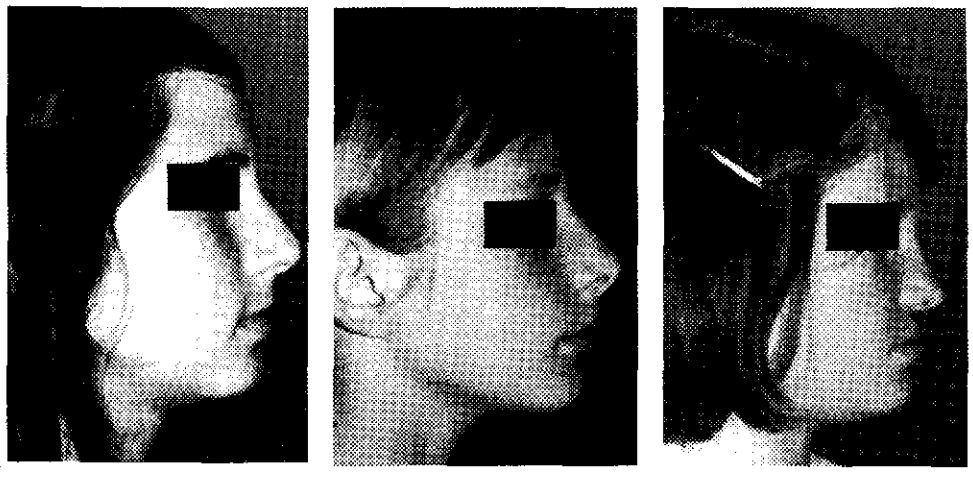


(a) *(b)* *(c)*

Fig. 2: Variations in profile convexity (a) retrognathic-convex (b) normal-near straight (c) prognathic-concave

planning does not overstep sensible boundaries and biomechanics are planned for the individual case the effects on the soft tissues will usually be within acceptable limits.

From the lateral view, with the patient's soft tissues at rest, assess the angle of profile convexity (Fig. 2). This is the angle formed by connecting glabella to subnasale to soft tissue pogonion. As the patient becomes more retrognathic the profile will become more convex. As the patient becomes more prognathic the profile will become more concave. The normal profile in the young patient is slightly convex but as the face matures the profile becomes less convex particularly in the male. Assess the shape of the nose, the naso-labial angle and the slope of the columella of the nose (Fig. 3) as well as the contours of the upper lip, lower lip and pogonion. If the lips do not meet at rest they are classified as incompetent. Assess the relation of the lips to the E line. Look particularly for evidence of a supra-mental groove and lip strain on closure which may be associated with an increased overjet and retrognathic mandible (Fig. 4). The contour and shape of the lips may be harmonious, narrow or full. If the lips are incompetent, ask the patient to bring the lips together lightly and assess the presence of undue lip strain or circum-oral muscular contraction. Observe the natural swallowing process without prompting the patient and whether the lips control the teeth in swallowing.



(a) *(b)* *(c)*

Fig. 3: Variations in the naso-labial angle (a) normal (b) increased (c) decreased

Construct the midline of the face and the inter-pupillary line. Check for facial asymmetry and volumetric differences between right and left sides (Fig. 5). Note the relationship between the dental midlines and the facial midline with the teeth in habitual occlusion. Note the general form of the face as tapering or square. The facial width proportions may be within normal limits (mesoprosopic), broad and square (euryprosopic) or long and narrow (leptoprosopic). These three categories equate very broadly with the mesofacial, brachyfacial and dolichofacial categories of Ricketts however they are not directly equivalent (Fig. 6).

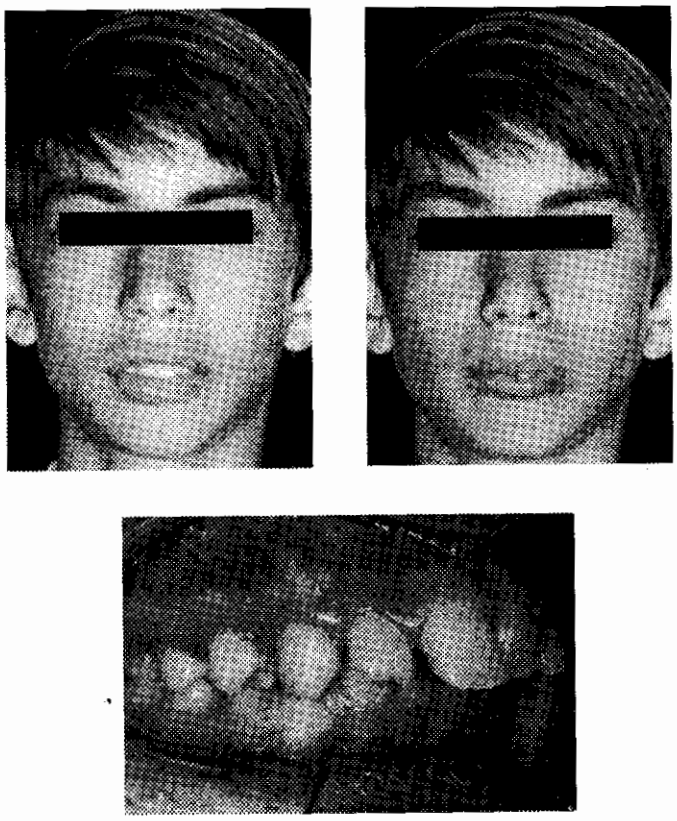
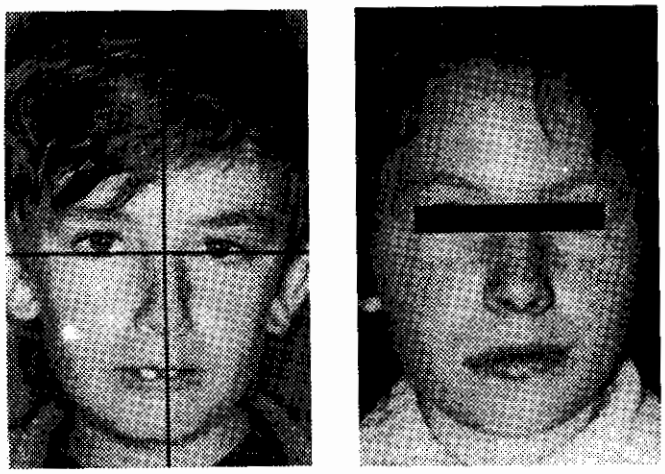
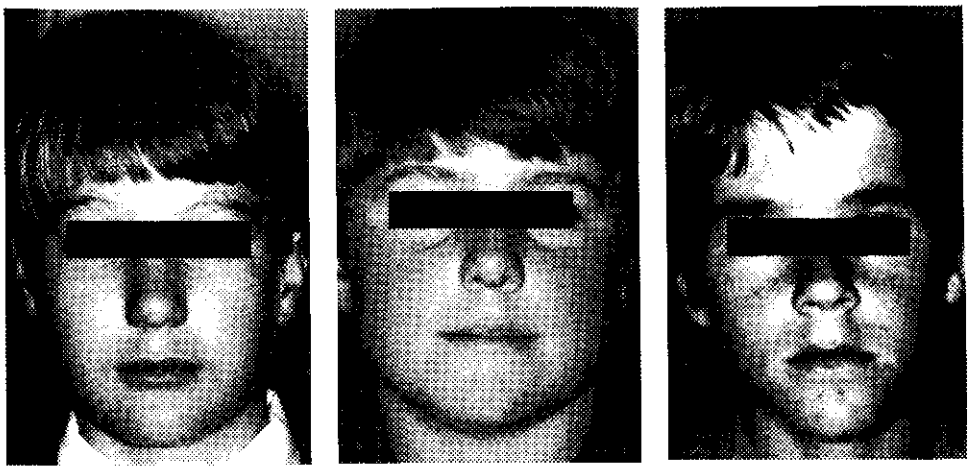


Fig. 4: Incompetent lips which are apart at rest. Closure requires contraction of the circum-oral musculature with the lower lip being trapped behind the upper incisors.



(a) *(b)*

Fig. 5: (a) Facial asymmetry with centre line discrepancy (b) volumetric difference between the right and left sides.



(a) *(b)* *(c)*

Fig. 6: Facial types (a) normal-mesoprosopic (b) broad square face-euryprosopic (c) long narrow face-leptoprosopic.

INDIVIDUAL SKELETAL VARIATION

Bjork (1955, 1963, 1966) using intra-bony metallic implants pioneered an accurate method for longitudinal study of individual growth changes and showed the degree of individual variation which may occur during growth of the cranio-facial skeleton. Rotation of the mandible during growth may occur in an anterior (forward) or posterior (backward) direction and growth of the mandibular condyle may vary from upward and forward to upward and backward (Fig. 7).

Bjork (1969) identified seven structural factors which were predictive of growth rotation including inclination of the condylar head, curvature of the mandibular canal, shape of the lower border of the mandible, inclination of the symphysis, interincisal angle, intermolar and interpremolar angulations and anterior lower face height. Skieller, Bjork and Linde-Hansen (1984) were able to correctly predict mandibular rotation in 86 percent of their sample.

Cases presenting with a curved mandibular canal, a pronounced symphysis which is angled forward, deep overbite and reduced lower anterior face height are predicted to display upward and forward condylar growth which is associated with anterior growth rotation of the mandible. In the more severe cases the lower border of the mandible and the gonial angle may show a rounded "rocker shape". Those cases showing a nearly straight mandibular canal, a less robust symphysis which is upright, reduced overbite and increased lower anterior face height are more likely to show upward and backward condylar growth with posterior growth rotation and a greater component of vertical growth (Fig. 8). Braumrind *et al* (1984) have questioned the ability of even experienced clinicians to estimate the growth rotation pattern.

Ricketts has distinguished three basic facial types – mesofacial (average), brachyfacial (square), dolichofacial (long). The mesofacial type exhibits facial

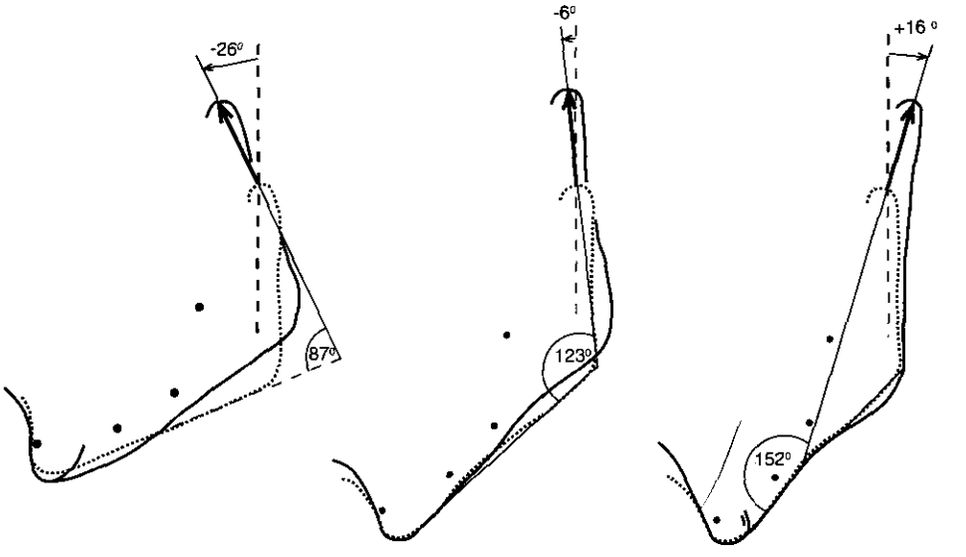


Fig. 7: Variation in the direction of condylar growth (a) upward and forward growth associated with anterior growth rotation (b) mean growth direction (c) upward and backward growth associated with posterior growth rotation.
(Redrawn from: Bjork A (1963): Variations in the growth patterns of the human mandible: Longitudinal radiographic study by implant method. J Dent Res 42: 400-11.)

characteristics whose values fall largely within accepted or normal ranges as defined by statistical parameters. However, a particular facial type does not imply the associated presence of a particular malocclusion. Facial types vary across the spectrum of malocclusions. Furthermore, normal occlusion may be seen in all facial types but as the type becomes more extreme it is likely that it will be associated with a malocclusion.

BRACHYFACIAL TYPE

The brachyfacial type is characterised by a square face. The classical brachyfacial characteristics include a reduced lower face height, a reduced mandibular plane angle, an increased facial axis angle and an increased mandibular arc. In the more extreme examples of this type, the lower facial area appears to be vertically compressed. Typically, in retrognathic brachyfacial types the soft tissue profile shows a supramental horizontal groove below the lower lip which is indicative of retropositioned lower incisors. Associated with the soft tissue pattern, the lower incisor to APo value is usually negative. The inter-incisal angle may be increased (more obtuse) and associated with a deep overbite particularly in the Class II division 2 brachyfacial type (Fig. 9). The method of Ricketts reflects the principles of morphological assessment enunciated by Bjork. Ricketts provided a relatively simple

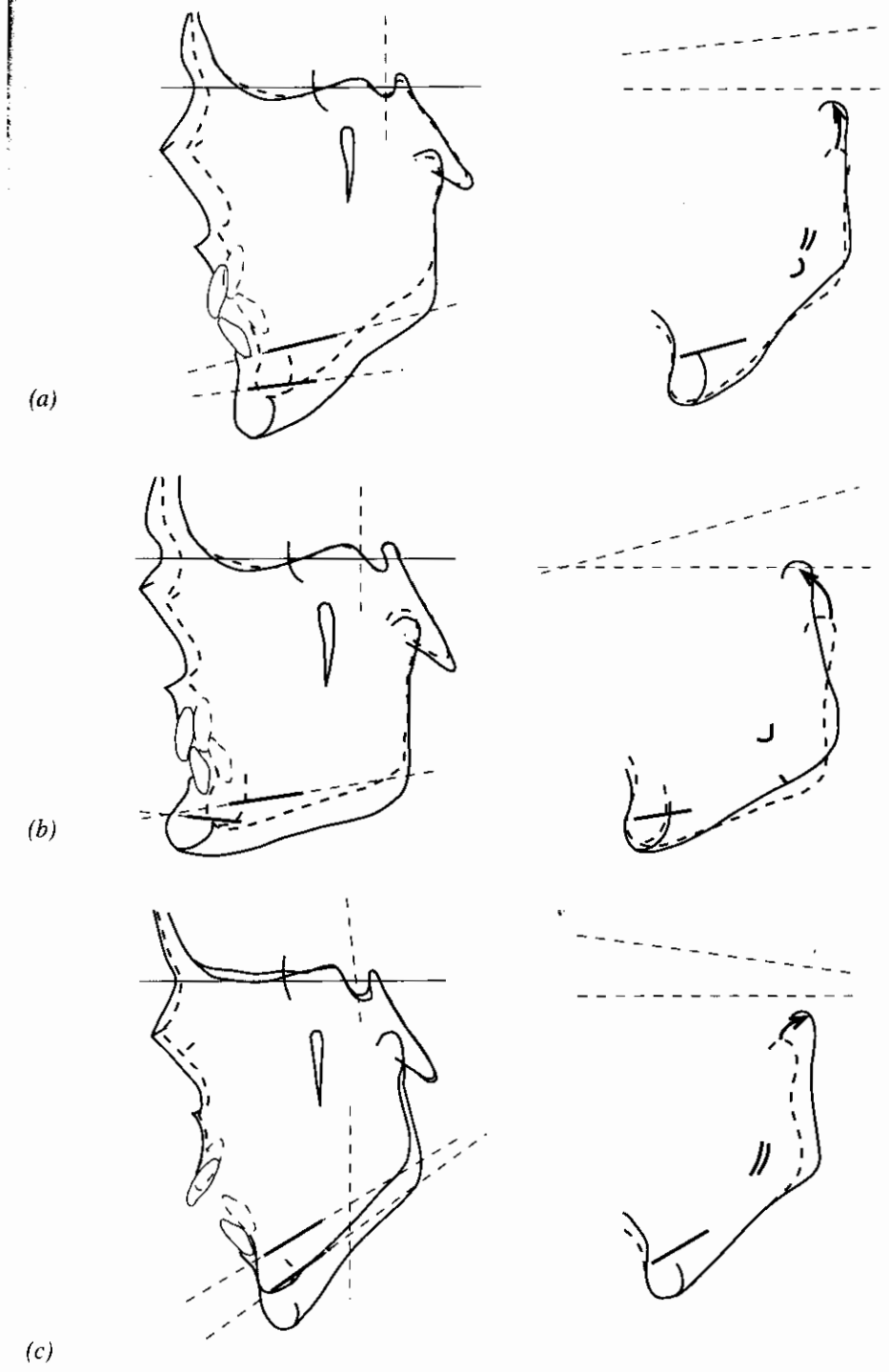


Fig. 8: Three types of mandibular growth rotation and the associated condylar growth directions (a) forward growth rotation, normal incisor occlusion and normal development of anterior face height (b) forward growth rotation, deep bite and reduced anterior face height (c) posterior growth rotation, anterior openbite and increased anterior face height. (Redrawn from: Bjork A (1963): Variations in the growth patterns of the human mandible: Longitudinal radiographic study by implant method. J Dent Res 42: 400-11.)

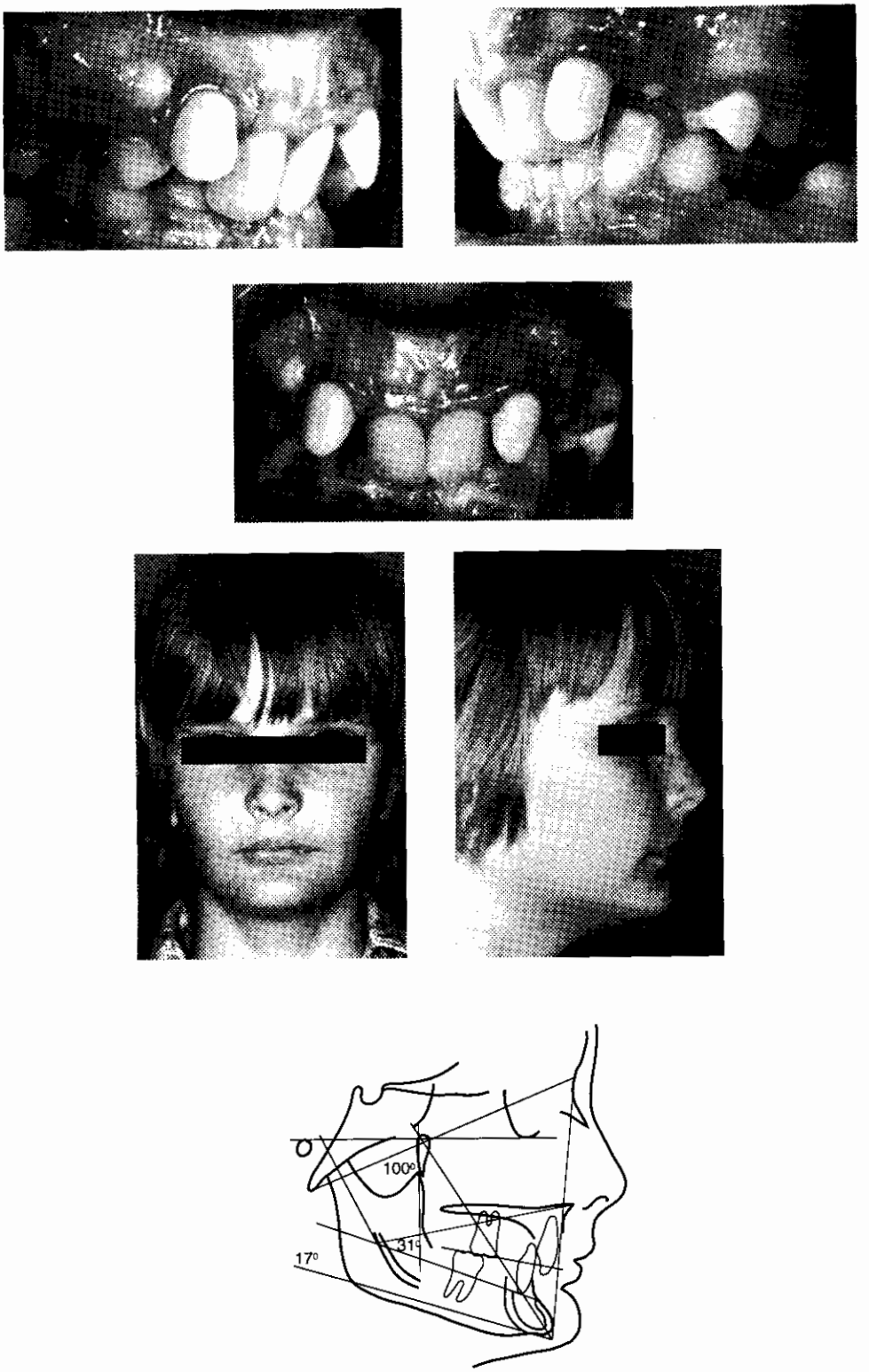


Fig. 9: Brachyfacial pattern with the traits which suggest anterior growth rotation and exacerbation of the deep bite.

numerical representation of the attributes which determine the underlying facial type.

The major objectives of treatment in retrognathic brachyfacial malocclusion types include reduction of the overbite and improvement of the inter-incisal angulation. The facial morphology can be expected to result in a slightly more horizontal growth pattern which will help to alleviate the mandibular retrusion in conjunction with suitable biomechanics. Extractions in the lower arch are often contraindicated because of the tendency to promote retro-positioning of the lower incisal segment and exaggeration of the underlying morphology. These factors mitigate against successful treatment with simple removable appliances although functional appliances may be particularly successful in selected cases. Severe cases may require orthognathic surgery.

DOLICHOFACIAL TYPE

The dolichofacial type is characterised by a long face with relatively less development of posterior facial height. The mandibular plane angle and anterior facial height are increased while the mandibular arc is reduced in conformity with Bjork's observations of a less curved mandibular canal. The facial axis angle is decreased reflecting the increased anterior face height. The incisor angulations may vary depending on the severity of the underlying skeletal pattern and the associated soft tissue patterns. The incisal overbite is usually not markedly increased and the more pronounced cases may have an open bite. The facial profile tends to be convex and the lower incisor to mandibular plane angle is variable. The mandibular symphysis is less prominent and in some cases the anterior surface of the symphysis may appear almost flat so that B point is not well defined by the alveolar curvature in this region. The decreased facial axis angle suggests a tendency to a vertical growth pattern and posterior growth rotation which may be expressed as a frank open bite in some cases. In contrast to the brachyfacial type, extractions may be better tolerated in the dolichofacial type in achieving treatment goals. However, the need for extractions is determined by the amount of crowding, incisor angulations and dental relationships and not solely by the skeletal pattern or facial type (Fig. 10).

GROWTH PREDICTION

Growth prediction is the term used to estimate the changes that will occur in facial dimensions over a given period of growth. Because of inherent inaccuracies it is usual to limit the prediction to two or three years. The process involves expansion of the craniofacial area using mean growth increments obtained from previous samples. Critics of the method claim that it is neither predictive nor reliable (Johnston, 1993). As a matter of caution it needs to be emphasised that treatment planning must always be a synthesis of the skeletal, muscular and dental elements, being further modified by factors such as compliance, age and the patient's objectives.

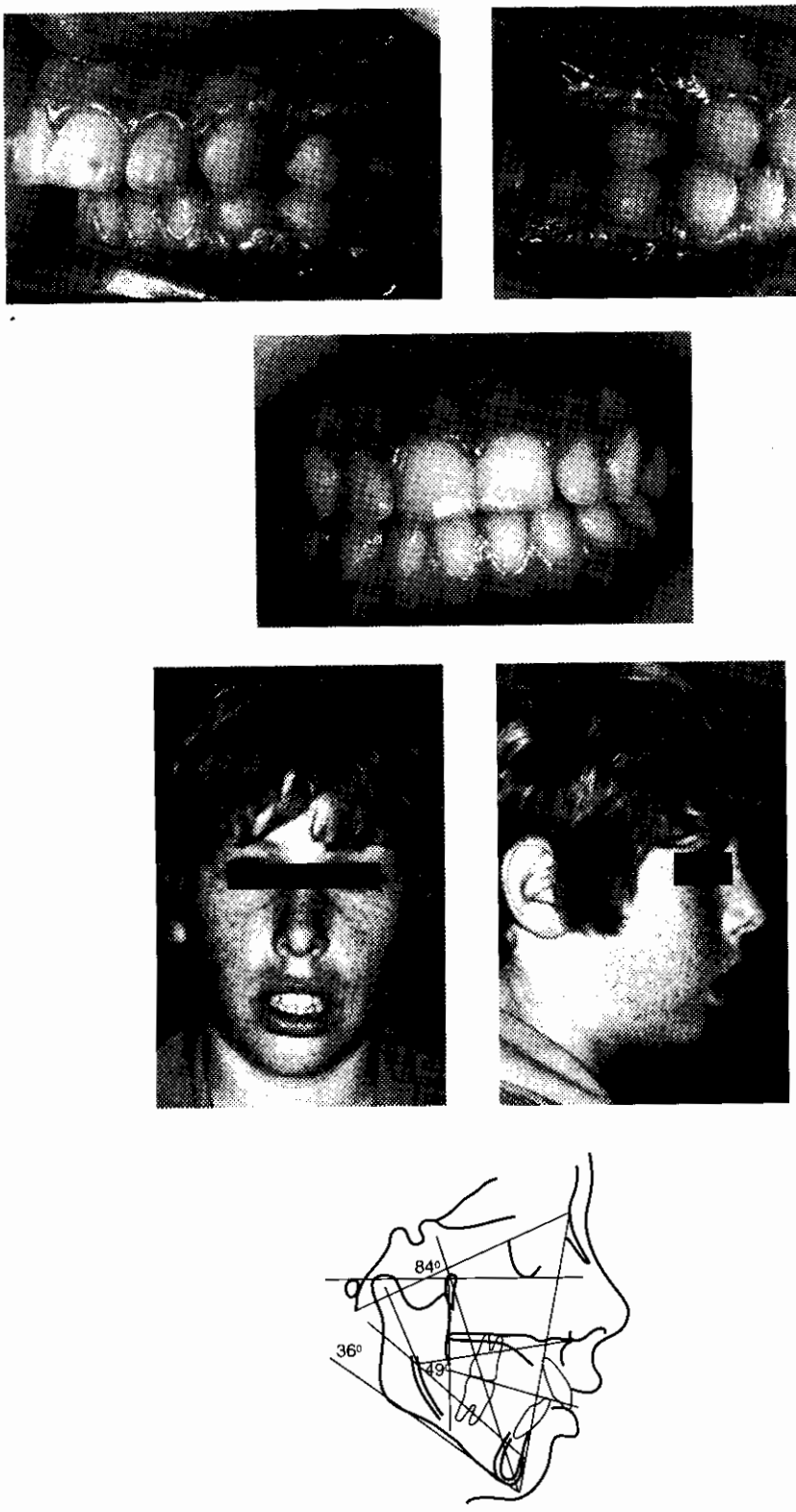


Fig. 10: Dolichofacial pattern with the traits which suggest posterior growth rotation and exacerbation of the open bite tendency.

A widely used method of growth prediction was introduced by Ricketts (1972) and is based on the hypothesis that growth expands along polar coordinates with their centre at pterygoid point where the fifth nerve passes from the foramen rotundum into the pterygo-maxillary fissure. Growth occurs in a gnomonic fashion so that defined points such as anterior nasal spine, nasion and gonion maintain the same polar coordinates, moving out in a sunburst pattern. This does not explain the mechanisms of growth but it does provide a model of expected growth in the absence of interference such as orthodontic treatment (Fig.11).

From his growth prediction model, Ricketts derived the Visual Treatment Objective (V.T.O.) whereby the additive effects of growth and treatment are 'predicted' providing the operator with an objective during treatment. Individual variations from the expected changes occur. The essence of growth prediction is that the direction of growth of the jaws reflects the underlying facial morphological type, as suggested by the work of Bjork. The mesofacial type, without treatment, will show neither opening nor closing of the facial axis. The brachyfacial type will tend to grow with slightly more horizontal emphasis giving natural enhancement of the chin and development of a strong symphysis. The dolichofacial type will tend to grow slightly more vertically so that the anterior face height becomes relatively longer than posterior face height. This tendency may be increased by orthodontic treatment.

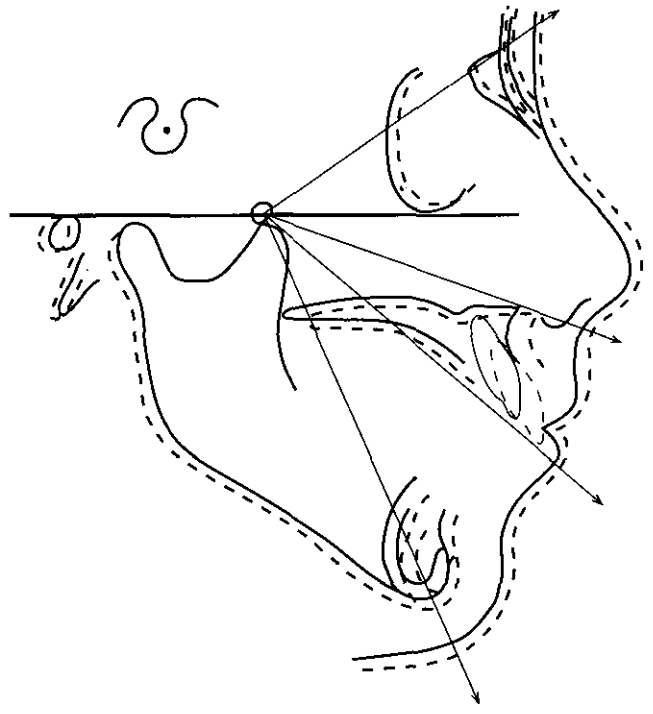


Fig. 11: Gnomonic growth pattern along polar coordinates centred at pterygoid point. Growth directions are dependent on the underlying skeletal morphology. Without treatment the underlying pattern is not expected to change on average even with growth.

Bishara and Jakobsen (1985) showed that most persons will have the same general facial type at age 5 years and age 25 years. In the majority of instances the underlying growth pattern will tend to maintain the original type. Most interestingly, they found that the growth curves in short, average and long facial types remained parallel and therefore the type differences persisted. However, occasionally, an individual growth pattern will depart from the expected pattern leading to uncharacteristic changes in facial dimensions. Burstone (1993) and others have drawn attention to the original skeletal type as an important aspect of post-treatment relapse.

SUPERIMPOSITIONS

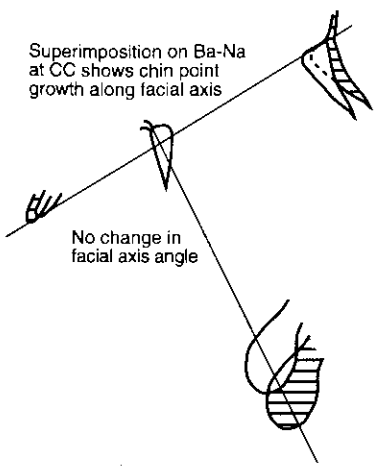
Growth is an important adjunct to orthodontic treatment, Ricketts recommended a growth analysis system which requires different superimpositions to examine different areas of the facial skeleton. He proposed the following superimpositions, remembering that the basic orientation reference line was the Frankfort plane and not the sella-nasion line used by Bjork (Fig. 12).

(a) superimposition at CC point along the basion-nasion cranial base line reflects the concept of growth along polar coordinates - in this instance the facial axis. On average, the mandible grows downward and forward along the facial axis with no change in the facial axis angle. Orthodontic treatment may alter this pattern and, in particular, may lead to opening of the facial axis and the mandibular plane angle.

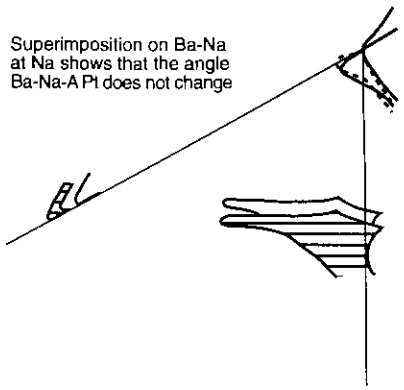
(b) superimposition along basion-nasion at nasion shows that with normal growth the angle Ba-Na-A Pt does not change and A Pt descends along the Na-A Pt line. Where A Pt convexity (A Pt to Na-Po) is increased, treatment may be specifically directed to retraction of the whole maxillary complex by means of orthopedic headgear. Where A Pt convexity is markedly reduced, reverse extra-oral traction may be indicated to protract the maxilla.

(c) superimposition on the palatal outline of the maxilla shows that, on average, the upper teeth move down and slightly forward with growth. The upper central incisor normally moves down its own long axis. Where the overjet is grossly increased and treatment is aimed at retraction of the upper incisors, considerable attention must be given to the final angulation of the upper incisors relative to the pre-treatment position and torque control of the upper incisor angulations may be required.

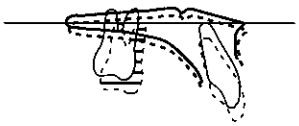
(d) superimposition at the origin of the polar grid shows the upper molar maintains the same relationship to the facial axis throughout growth with the mesiobuccal cusp lying on the facial axis. In addition, the distance from the upper molar point to the pterygoid vertical line increases with age by 1mm each year. The normal value is given by the formula (age + 3mm). Any marked reduction from this expected value is an indication that the third molars may not have sufficient space to erupt and headgear treatment may compound the problem.



(a)

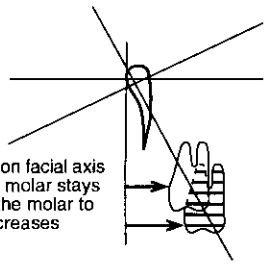


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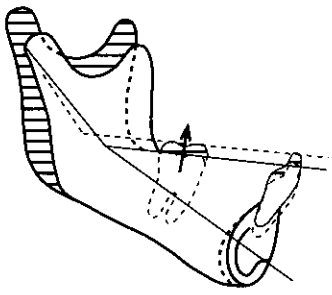


Superimposition on ANS-PNS
at ANS shows incisors erupt
along their long axes. Molars
erupt slightly down and forward

(c)



(d)



Superimposition on mandibular
corpus at Pm to evaluate lower
dentitional changes

(e)

Fig. 12: Local superimpositions to show the expected movement of structures with growth and without orthodontic treatment. (After Ricketts.)

(e) superimposition of the mandible at protuberance menti along the corpus axis shows that on average the lower teeth erupt vertically so that the functional occlusal plane remains parallel to previous positions. This superimposition position is important in evaluation of the movements of the mandibular teeth, particularly the incisors, within the mandible itself as opposed to the face as a whole.

Each one of these superimpositions is designed to show local changes in a specific area as a result of growth or treatment. Where treatment is undertaken, we will see changes in these local areas which differ from the changes which could be expected from growth alone, as described above. For example, in a case receiving headgear treatment, the upper first molar will not maintain the same relationship to the facial axis line but will move back in relation to it. In another case where the lower arch is subjected to Class II traction, we might expect to see some forward as well as upward eruption of the lower teeth in relation to the corpus axis line. This breakdown into separate superimpositional areas helps overcome a major difficulty of cephalometric analysis, namely confusion of the additive effects of growth and treatment when superimposition is done on a single cranial base line such as Se-Na or Ba-Na.

CAUSE OR EFFECT

Considerable effort is devoted to the detailed characterisation of types of malocclusion. The relationships between morphology, function and etiology are extremely complex. It is tempting to explain one in terms of the others. The problem is that it is not possible to control for the genetic makeup of the types in question and therefore it is usually not possible to reach robust conclusions about the relative importance of the genetic and environmental components of the etiology of a particular condition. Morphology and function are seemingly correlated in many instances but the etiological connection between them often remains obscure. In very broad terms, most orthodontic treatment is based on the assumption that maloclusions of a similar type will have a similar derivation and therefore require a similar treatment approach.

Some research suggests that vertical growth is enhanced where the growing patient lowers the mandible to achieve a better airway thus encouraging overeruption of the buccal teeth and posterior growth rotation of the mandible. However, the evidence is equivocal. Solow and Siersbaek-Nielsen (1991) pointed out that, on average, subjects with increased cranio-cervical postural flexion (head forward) show reduced forward growth rotation of the mandible whereas subjects with reduced cranio-cervical flexion (head back) showed increased forward growth rotation of the mandible. They have postulated that the airway problems are a symptom rather than a cause of the aberrant growth pattern.

Other research suggests that facial form may contribute to intermittent recurrent upper airway obstruction during sleep (obstructive sleep apnoea). It has been postulated that in OSA subjects the airway is narrowed because of mandibular retroposition associated with increased lower face height, open bite, large gonial angle and a steep mandibular plane angle. However, a direct relationship between morphology and OSA is not found in every case. The circularity of this and similar discussions becomes apparent and suggests the need for caution in interpolating the etiology and recommending treatment based on it.

Contemporary orthodontic treatment is substantially influenced by growth patterns and their association with different morphological types. There is also some evidence that post-treatment stability may be influenced by the original facial type. Growth analysis is a very imperfect exercise which relies on the persistence of the underlying individual pattern. The clinician attempts to set treatment objectives based on the interaction of biomechanics and expected growth in the younger patient. Angle's classification persists as a coarse descriptive tool but it does not reflect the complexity of variation in underlying morphological types. Within any one of Angle's classes, a range of morphological combinations may be evidenced and each type will require different considerations in treatment planning.

These factors are central to the issue of growth modification in orthodontics using various appliances. Can the environment be satisfactorily controlled? Is the duration of observation long enough to allow for relapse or regression? Is the genetic etiological component an over-riding factor? New clinical treatments must always be regarded with caution even though they may seem to provide correction — at least in the short term. We have a poor understanding of the interaction of etiological factors associated with most significant types of malocclusion. Essentially we must use morphological comparisons to achieve consistency of treatment planning.

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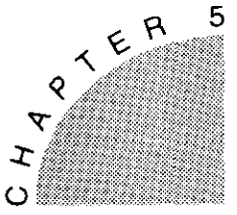
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FUNCTION

The functions of the circumoral muscles include speech, respiration, mastication, swallowing and posture. Function is to be considered in the etiology, development and treatment of malocclusion and may impinge on clinical deliberations in the following ways:

It is an impetus to normal growth and development. Abnormal function may modify development, leading to an abnormal occlusion.

It may directly influence the course of orthodontic treatment and the appliances used in treatment. It may also subsequently affect retention of the completed result.

Normal functional patterns of jaw movement support the integrity of normal occlusion and a normal temporomandibular joint.

Some functional patterns are amenable to change with orthodontic treatment, usually in conjunction with alteration of the positions of the teeth. For example, where the upper incisors were proclined outside the lower lip and are corrected, it is hoped that the changes in soft tissue activity occurring with the changes in tooth positions will establish a new balance which maintains the corrected positions of the teeth. Not all anomalous functional patterns are correctable by orthodontic treatment. An anterior open bite associated with a strong tongue thrust may be particularly resistant to change. Any correction achieved may be subject to relapse.

ZONE OF BALANCE

Normally the teeth of the upper and lower jaws are in a state of relative stability within the supporting tissues. Over extended periods, the basic form of the occlusion does not change noticeably. The teeth occupy positions within a zone of balance created by the buccal and labial musculature, the tongue and dental contacts. Vertically, the teeth are in balance between occlusal forces and eruptive forces. Occlusal forces do not intrude the teeth. They maintain the occlusal levels of the upper and lower teeth so that the inter-maxillary or freeway space of 2-3mm is preserved. As the patient grows and the inter-maxillary height increases, the teeth gradually erupt, but not beyond that level required to preserve the freeway space. There is a very delicate balance between the actions of the muscles, the periodontal ligament, the levels of the teeth and the occlusal forces generated in function.

The balance of forces is not necessarily stable over a life time. Changes in the occlusion from the stage of complete eruption of the second permanent molars to old age do occur with slight changes in jaw relationships, occlusal wear and often

an increase in the amount of crowding. The zone of balance may be altered by loss of periodontal integrity, loss of major supporting permanent teeth, erupting teeth such as third molars or abnormal habits. These factors may cause the teeth to become unstable because of an imbalance between forces. In older patients the progressive drifting and spacing of the teeth is sometimes seen (Fig.1).

SWALLOWING AND TONGUE THRUST

Swallowing occurs many times each day and involves the circumoral tissues. Normally it is associated with light closure of the teeth and contact of the lips without marked contraction of the circumoral muscles. During swallowing the floor of the mouth is raised and the tongue compressed against the teeth and palate in order to clear the mouth of saliva. The normal mature swallow is an unobtrusive act.

At birth, the swallowing pattern is quite different from that in the mature adult. During suckling the milk passes down a furrow in the tongue and then either side of the relatively high larynx and it seems that suckling and respiration may occur at the same time. However, a discrete definitive swallow occurs when the infant is not suckling. In the absence of any teeth, the tongue contacts the lips between the gum pads. The tongue often lies in a forward contact position at rest in the infant. As the child matures, the teeth erupt and more solid food is ingested. The tongue acts as a transport mechanism for the bolus of food and normally the swallow is contained within the framework of the teeth in occlusion. There is relatively little active contraction of the lips except in cases where they are morphologically inadequate and must be contracted to obtain an oral seal. During drinking or swallowing soft semi-liquid foods, the teeth do not come together. The tongue contacts the lips and cheeks and is raised by the floor of the mouth to propel the liquid down the throat.

On occasions the infantile tongue-to-lip activity may persist into childhood with active contraction of the lips and tongue against each other, associated with some lowering of the mandible to accommodate the tongue-lip contact. Synonymous terms for this type of activity are atypical swallow, reverse swallow or visceral swallow. In some children this tongue-lip activity may be so persistent that it is thought to be an inherited trait and, therefore, is termed an endogenous tongue thrust (Fig. 2). Whatever the inherent cause, the persistent activity and lip-tongue contact may cause a reduced overbite or open bite and may also be associated with a speech abnormality, namely a lisp. Some workers prefer to distinguish between a primary tongue thrust and a secondary or adaptive tongue thrust, the distinction being that the primary tongue thrust itself causes a malocclusion while the secondary tongue thrust is a response or adaptation to a morphological problem.

In severe Class II malocclusions with increased overjet, an anterior oral seal may be formed by contact of the tongue with the anterior palate, teeth and the contracting lips. The posterior teeth will usually be separated. In very severe cases the upper lip

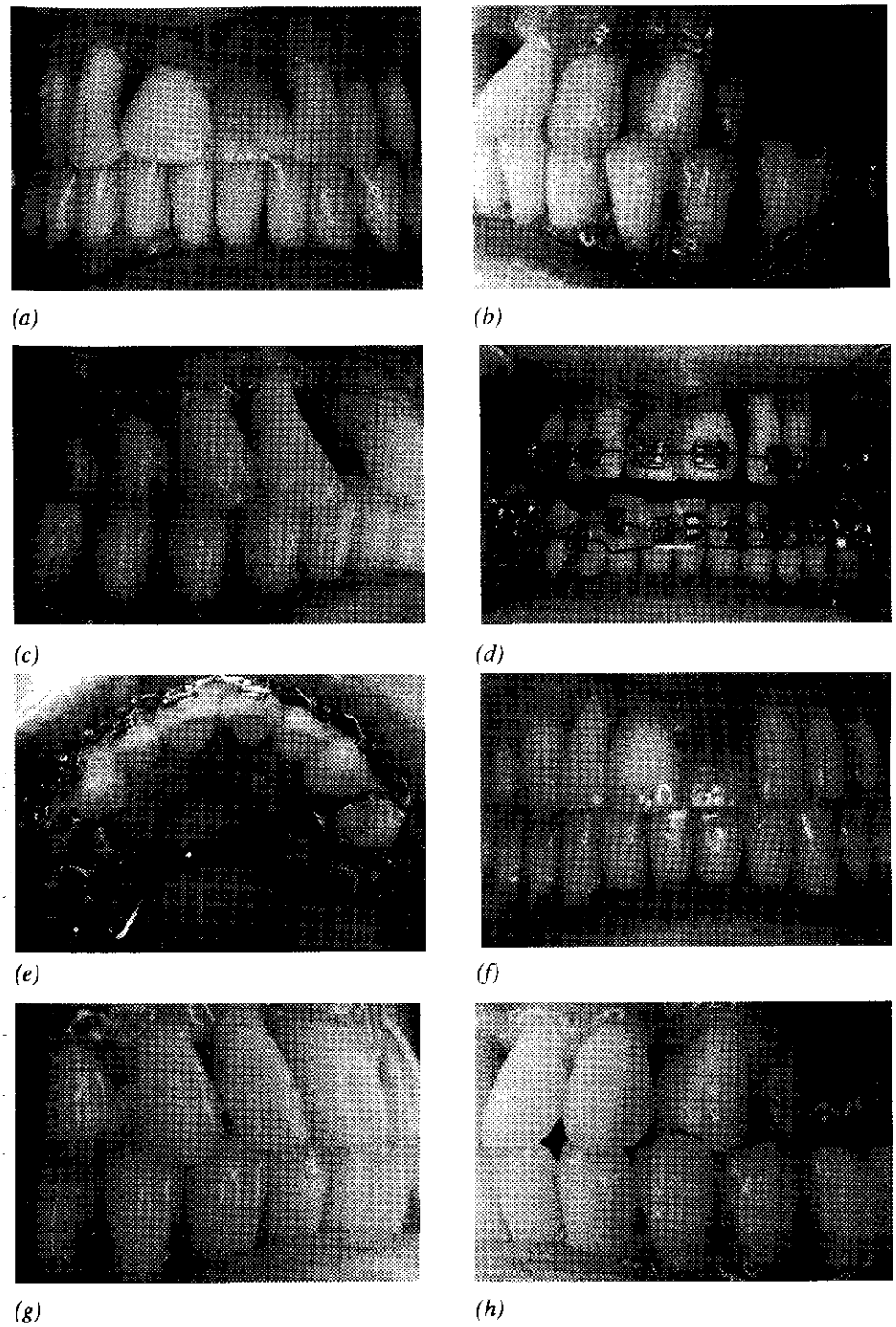


Fig. 1: Series of photographs showing a case with periodontal bone loss and drifting of the teeth. Treatment consisted of rigorous periodontal management, space closure and permanent retention with lingually bonded retainers and an upper removable appliance. (a,b,c) Pre-treatment. (d,e) During treatment with palatal stabilising arch to compensate for loss of posterior teeth. (f,g,h) Post-treatment.

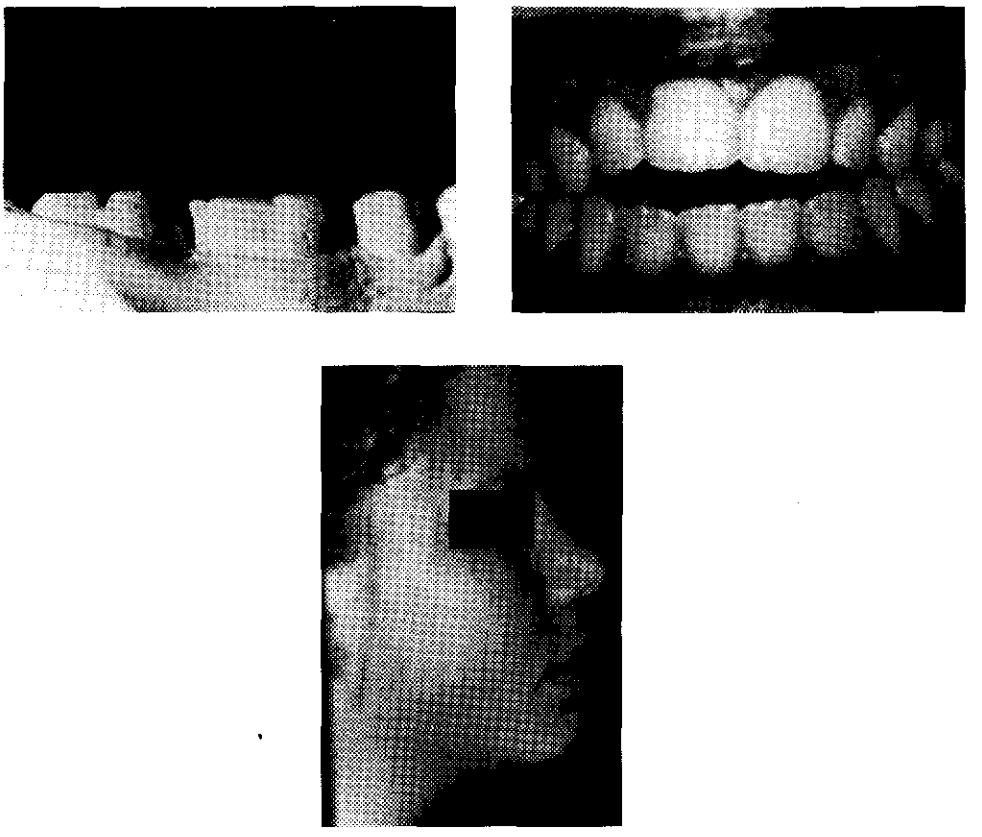


Fig. 2: Endogenous tongue thrust with anterior openbite and excessive wear of the posterior teeth. The patient spoke with a lisp and there was a tongue thrust with tongue to lower lip contact in swallowing.

may become redundant to the swallowing process and the anterior seal is achieved between the tongue, palate, teeth and lower lip (Fig. 3). The net result may be an incomplete overbite or open bite particularly in the presence of an associated digit sucking problem. Adaptive swallowing habits may also occur in severe Class III malocclusions with marked reverse overjet and incomplete reverse overbite with the tongue forming a seal against the contracting lips (Fig. 4).

While superficially it may seem possible to distinguish between primary and secondary swallows in all cases, this may be very difficult in reality. Therefore the likelihood of relapse after treatment is not always predictable. In the case of the endogenous tongue thrust the tongue is more likely to be clearly visible between the teeth at rest, during speech and swallowing. The patient frequently speaks with a lisp and even at rest the tongue lolls against the lips. Speech patterns are learned but may be conditioned by underlying inherited motor neurone patterns. Some speech impediments run in families and are occasionally evident in several generations. Some muscular patterns are certainly familial and can be observed in different members of the same family.

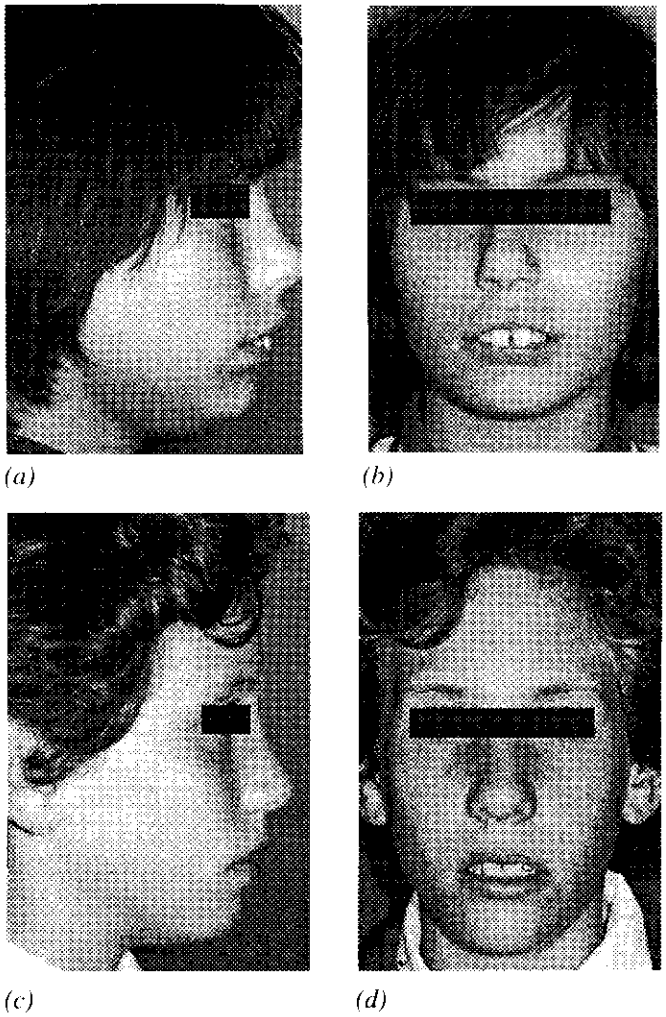


Fig. 3: (a,b) Patient with incompetent lips, a severe Class II malocclusion, lower lip trap and tongue to lower lip seal on swallowing. (c,d) Patient with morphologically incompetent lips which were contracted to form an adequate anterior oral seal on swallowing with no effects on the incisor positions.

In many young patients a tongue thrust will gradually diminish as they mature and the openbite will improve if not close completely. But where the problems persist the orthodontist may have no alternative but treat on a trial and error basis and to closely watch for any 'see-saw' effect on the teeth where they are moved one way by the tongue and the other way by the appliance. This type of reversal is known to be an important cause of root resorption. Treatment is usually directed to preventing tongue thrust and any sucking habits by means of a tongue crib or wire cage behind the upper incisors.

An interesting aspect of many anterior open bite cases is the presence of multiple posterior wear facets and poor dental interdigitation (Figs. 2, 5). The intercuspal [redacted]tionship in centric occlusion seems indefinite and suggests a lack of effective [redacted]proprioceptive feedback to ensure a definitive occlusal contact position. This same

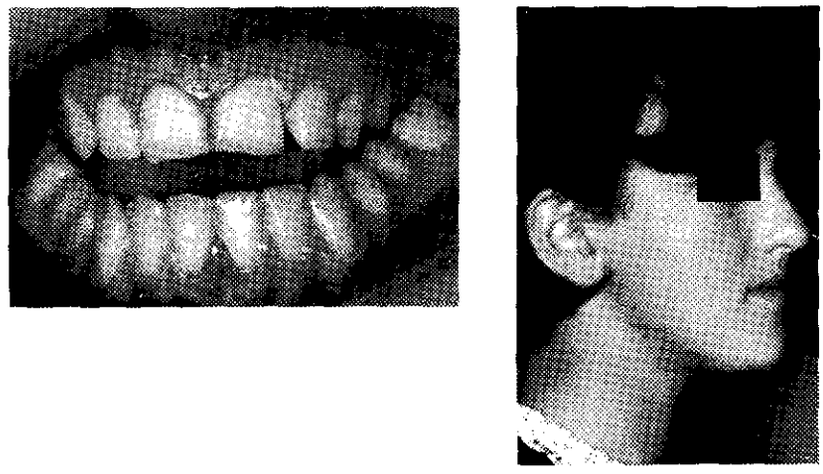


Fig. 4: Severe Class III malocclusion with anterior openbite as a result of the skeletal pattern. The patient exhibited an adaptive tongue function contacting the lips on swallowing to complete the functional oral seal.



Fig. 5: Severe anterior openbite in a patient aged 13 years associated with a tongue thrust which was judged not to be endogenous. Note the excessive wear of the posterior teeth. The openbite was corrected with Class III elastics and anterior box elastics to the upper and lower incisor segments.

uncertainty seems to typify the movements of the tongue. Many of these children also lack effective oral clearance on swallowing. The occlusal pattern defies the accepted tenets of normal occlusal interdigitation and seems to remain in this "indefinite" state irrespective of the type of corrective treatment undertaken. Could it be that the primary fault is in the underlying muscle physiology?

An abnormal swallow, pinched narrow nares, a narrow palate and increased overjet may occur together. In some cases the removal of tonsils and adenoids is undertaken to overcome airway problems although this practice has diminished significantly in recent years. In other cases substantial lateral expansion of the maxillary arch is advocated. The implication is that poor development of the maxillary arch and obstructed nasal respiration are interdependent. Children must be proven to be true

mouth breathers and all aspects of the condition assessed in conjunction with an appropriate medical specialist with due consideration of factors such as allergic rhinitis which may cause an intermittent airway obstruction problem. However, where a child presents with maxillary arch constriction, nasal respiration should be evaluated. In very general terms it should be expected that maxillary orthodontic expansion alone will not permanently relieve nasal airway problems.

The ultimate occlusion of the teeth is a composite of many factors including the underlying skeletal pattern, resting and functional muscular patterns and the inherent growth pattern. Abnormal muscular patterns associated with developing malocclusions should not be ignored and if interceptive treatment is required it is aimed at the abnormal muscular function as much as at the malocclusion. But it needs to be emphasised that the modification of muscular patterns in the hope of substantially altering the underlying pattern is not a reliable procedure. On occasions specific action may be directed at functional anomalies such as digit sucking or tongue thrusting where the effects are more localised to the dento-alveolar area. Remember that as each individual matures the circum-oral soft tissues also mature. It is interesting to judge the prevalence of incompetent lips in children compared with adults where the rate is much lower. Endogenous problems may also improve with age, becoming less obtrusive as the size of the circum-oral structures increases.

FINGER AND THUMB SUCKING

Digit sucking is relatively common in infants and young children, yet it causes few problems in some cases. If the habit is very persistent and the duration of sucking each day is lengthy, the resultant forces will overcome the zone of balance and move the teeth to abnormal positions or prevent normal development (Fig. 6). There is no predictable relationship in so far as a child may exhibit a digit sucking habit but if neither the force nor the duration is sufficient to overcome the zone of balance, the occlusion may remain relatively unaffected. Occasionally persistent digit sucking on one side may cause a unilateral open bite.

However, prolonged and active digit sucking is capable of quite serious effects on the teeth. It may cause proclination of the upper incisors, retroclination of the lower incisors, distortion of the associated alveolar bone, failure of vertical development of some teeth and general contraction of the upper arch leading to a unilateral or bilateral crossbite, perhaps with a mandibular slide on closure to centric occlusion (Fig. 7). Of course, not all of these effects will necessarily occur in a particular individual.

An anterior open bite associated with digit sucking may be due either to prevention of eruption of one or more teeth or over eruption of posterior teeth because of the constant depression of the mandible required to accommodate the thumb. The condition may be exacerbated by thrusting of the tongue into the space. On occasions it may be quite difficult to determine if the initial abnormal functional activity is the

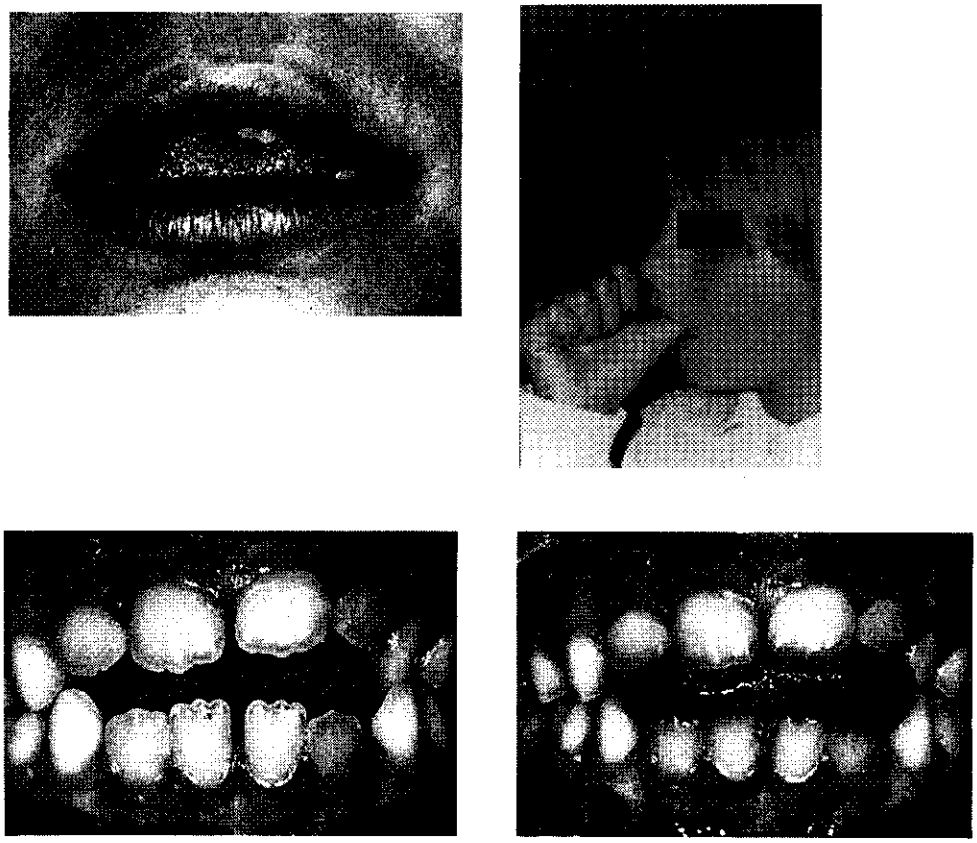


Fig. 6: Patient with an avid thumb sucking habit causing an anterior open bite associated with a tongue thrust.

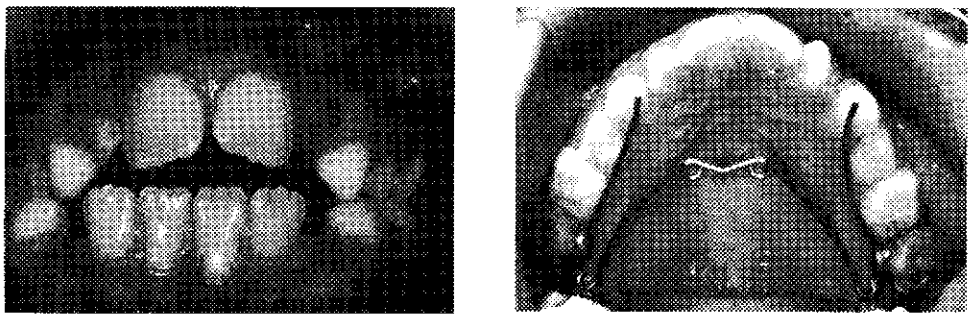


Fig. 7: Thumb sucking habit has caused slight proclination of the upper incisors, an anterior openbite associated with a tongue thrust and contraction of the upper buccal segments into lingual crossbite. Treatment included lateral expansion with a quad-helix appliance.

digit sucking or the tongue thrusting. Contraction of the upper arch associated with digit sucking is thought to be due to a failure of the tongue to counteract the forces of the buccal musculature. During digit sucking the mandible and tongue are depressed to accommodate the digit in the mouth. The increased activity of the buccal musculature and the generation of a negative intraoral pressure cause a gradual contraction of the arch to the point where cuspal interference occurs and the mandible deviates to left or right to avoid the interfering contacts. At this point one side moves into full crossbite while the other side achieves a false normal relationship (Fig. 8).

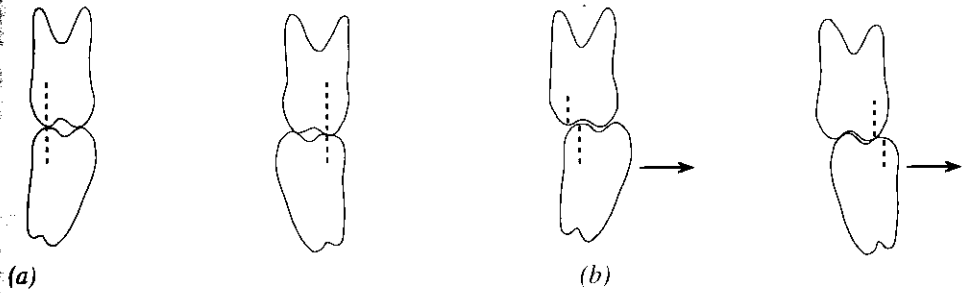


Fig. 8: (a) Bilateral cusp-to-cusp occlusion is caused by contraction of the upper arch (b) the resulting cuspal interference is accommodated by a lateral displacement to centric occlusion with an apparently normal occlusion on one side and crossbite on the other side.

Persistent active digit sucking with signs of dento-alveolar distortion should be treated interceptively and the aim of treatment in many instances is simply to stop the sucking habit and let natural improvement occur. Some form of fixed appliance which impedes insertion of the digit is preferred. This can be a fixed palatal arch with an anterior cage. The design should be varied to suit the patient. The clinician must endeavour to positively and pleasantly encourage the child to stop the habit. However, experience shows that some children will not stop and may become quite distressed at the interference. In rare cases, the clinician must remove the appliance to allow the habit to continue. One of the strongest disincentives to a digit sucking habit is peer pressure and as the child moves into higher school classes the habit becomes a matter of comment both at home and at school. Interestingly, prolonged nagging by parents to stop the habit mostly seems to have the reverse effect.

RESPIRATION

An association between abnormal respiration and some forms of malocclusion has been supported by the research of Harvold et al (1981) on monkeys which has shown that artificial nasal obstruction leads to the development of malocclusion with openbite. The conditions prevailing in the experimental model were extreme. The types of malocclusion observed were variable due to different responses by the animals in order to achieve an oral airway.

Human research data in this field is suggestive rather than conclusive. The general proposition is that nasal obstruction forces the subject to breathe oro-nasally with

an associated depression of the mandible to achieve an oral airway. We do not know if partial obstruction causes a partial problem. However, treatment of the nasal obstruction does tend to improve the situation in some cases.

LIMITS OF INTERCEPTION

The concept of a causal relationship between morphology and function stems in part from the effects of specific clinical anomalies. For example Kiliaridis et al (1989) studied the association between myotonic dystrophy of the masticatory and facial muscles and aberrant craniofacial morphology (Fig. 9). The disease is characterised by progressive muscular weakness and atrophy. They found a typical facial morphology including increased facial height, failure of mandibular development, increased mandibular plane angle, open lip posture, openbite and posterior crossbite. In contrast, a patient suffering from fascio-scapulo-humeral dystrophy is shown (Fig. 10). In this instance, the condition has specifically affected the labial facial musculature but not the main masticatory or lingual muscles which function normally. There is proclination of the upper and lower incisors and anterior openbite due to unrestrained action of the tongue which is protruded to form an oral seal against the inactive lips. Otherwise the skeletal pattern is within normal limits.

The discussions concerning the relative etiological importance of genetic and environmental factors are as old as biological science itself. The matter is not yet resolved but the available evidence suggests that we are not able to influence growth beyond genetically determined limits by increasing functional stimuli beyond the normal day-to-day levels. Much of the evidence in favour of the notion of growth

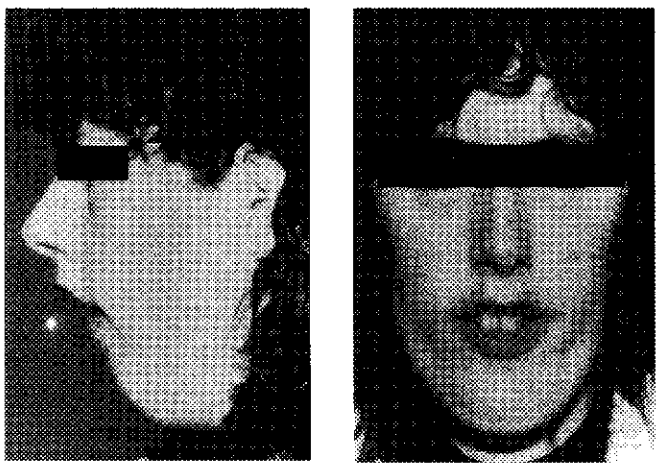


Fig. 9: Patient with myotonic dystrophy of the masticatory and facial muscles characterised by progressive muscular weakness and atrophy. The resulting facial morphology includes increased facial height and openbite. (From Kiliaridis S et al (1989): Muscle function and craniofacial morphology: a clinical study in patients with myotonic dystrophy. Europ J Orthod 11: 131-8.)

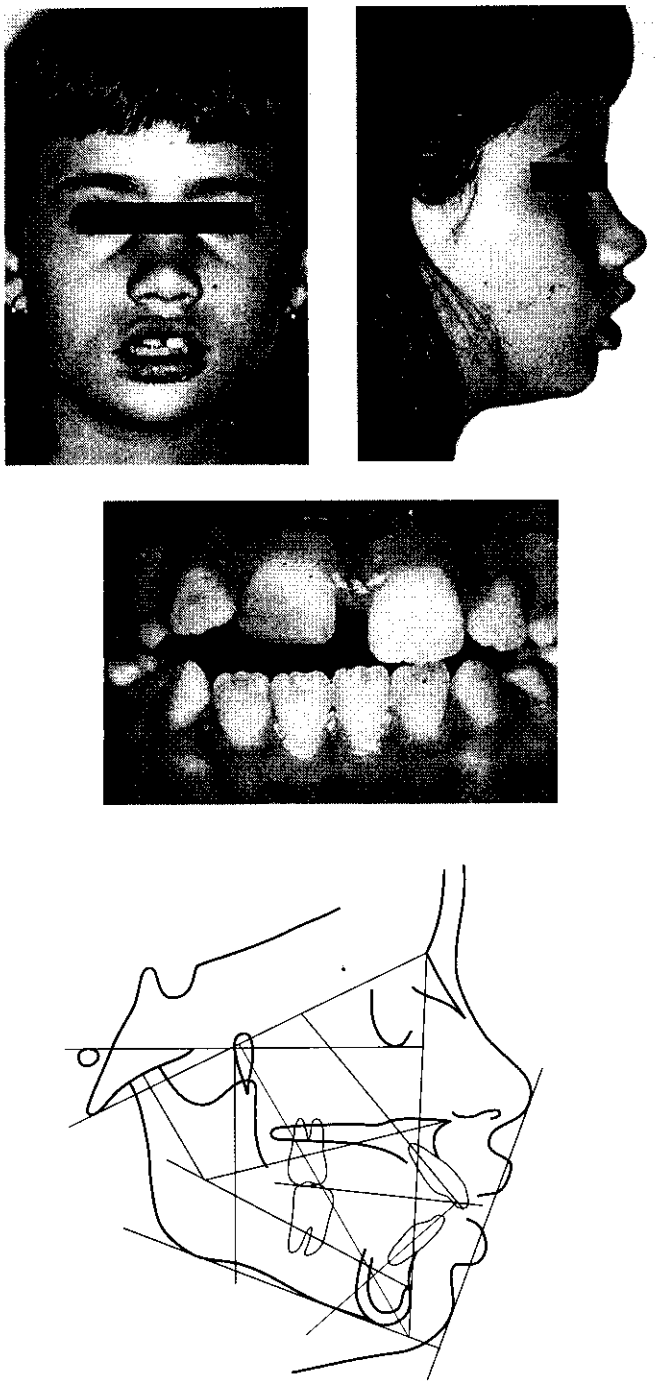


Fig. 10: Patient with fascio-scapulo-humeral dystrophy which affected only the labial muscles of the face. The skeletal pattern is within normal limits but the uncontrolled pressure from the tongue has caused upper and lower incisor proclination.

modification relies upon evidence obtained from patently abnormal situations. This does not prove that normal growth can be enhanced under normal conditions. In general our knowledge of the control of growth processes is limited. Our working

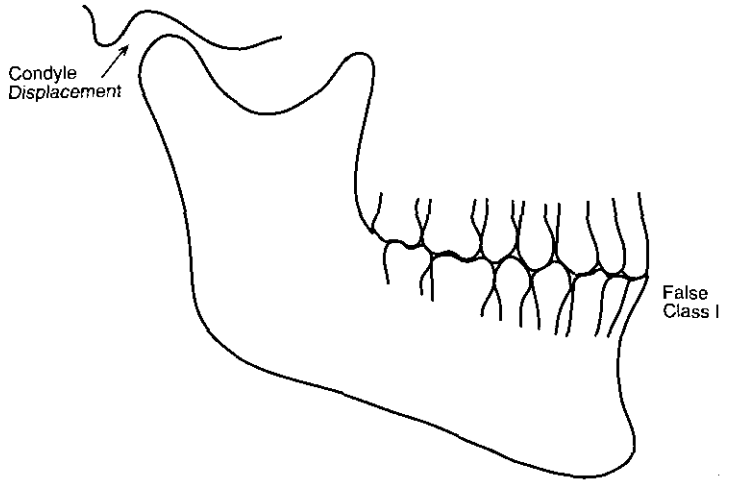
hypothesis is that in the presence of normal function and normal diet, growth will reach genetically determined limits.

The main question which arises from these considerations of function is just how much can the developmental growth processes be changed with modifications to the functional environment? Early workers felt that orthodontic treatment was able to alter the environment to achieve a normal occlusion with a full complement of teeth although there were some notable opponents to this view. Brash (1956) was more inclined to support the theory of the primacy of heredity over environment. The Frankel appliance is specifically designed with buccal shields and pads which induce vestibular stretching, periosteal stimulation and basal bone development with expansion of the dental arches. Correct implementation of the Frankel regime is demanding and case selection is important. There is still some doubt whether its effects are due to growth stimulation or dento-alveolar modification. More recently there has been a revival of the concept that aberrant dento-skeletal development may be overcome by functional appliances designed to optimise growth and the functional matrix. The evidence supporting this view is unconvincing (DeVincenzo, 1991).

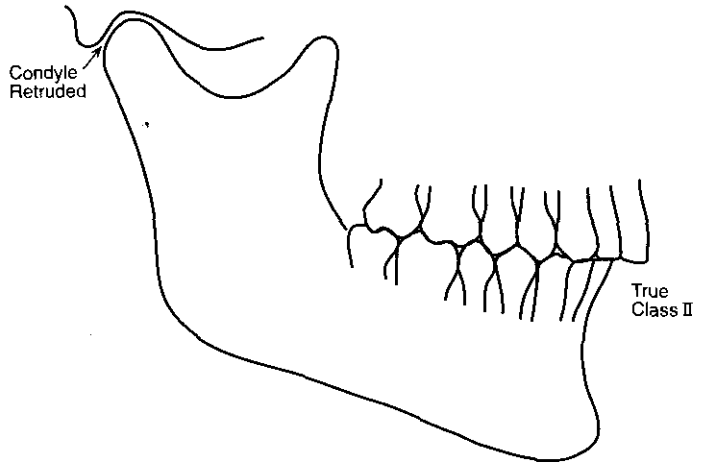
Continuing research and experience have drawn attention to several important points. Treatment with or without extractions cannot be guaranteed to remain absolutely stable over the long run and relapse of the malpositions of individual teeth and recurrence of crowding are relatively common (Little et al, 1981). Usually the relapse is not total so that the considerable improvement remains. Additionally, it has become clear that some skeletal anomalies are not satisfactorily treatable by orthodontics alone. Orthognathic surgery will often provide a quicker and more predictable course of treatment in these cases although relapse after surgery is also a consideration.

The general approach to etiology and treatment has become noticeably more conservative. While heredity is known to control the underlying growth potential of the individual, that potential may not be realised in the presence of abnormal function. There is no all-or-none relationship between function and form. Functional influences result from a wide variety of activities and their net effect may still promote growth to the full potential. The more intriguing question relates to the use of interceptive techniques in not only correcting abnormal function but in changing the functional envelope so that an inherited trait is minimised by promoting development beyond that normally expected.

Some research indicates that growth at the mandibular condylar cartilage and the articular fossa can be influenced by displacement of the condyle away from the articular fossa. This may be more predictable where that displacement is continuous, such as with the Herbst appliance, rather than intermittent, as with the Andresen monobloc. However, evidence also indicates that these effects are largely an acceleration of the natural growth processes and after growth has ceased there are no significant differences in mandibular dimensions between subjects treated with functional appliances and control subjects. This does not mean that functional



(a)



(b)

Fig. 11: (a) False Class I occlusion achieved by a forward mandibular posture (b) retrusion of the mandible to the retruded contact position reveals a true Class II occlusion with increased overjet.

On occasions the proprioceptive responses guiding abnormal mandibular function may be so strong as to make it very difficult to manually reduce the mandible to a retruded unstrained central position. In extreme cases, particularly in the presence of pain, a period of bite splint therapy may be required. Radiographic joint examination may be a valuable diagnostic aid in determining the condition of the fossa or condyle. However radiographs are of limited value in determining the status of condyle-disc-fossa relationships.

TEMPOROMANDIBULAR DYSFUNCTION (TMD)

Two main theories of balanced occlusion have gained acceptance – canine rise and group function. As the mandible moves laterally the canine rise theory suggests that the upper and lower canines act as guides to separate or disclude the posterior teeth. The group function theory postulates a fully articulated contact of most of the posterior teeth on the working side. In protrusive movements, all the posterior teeth should disclude and as the lower anterior teeth ride over the palatal surfaces of the upper anteriors, the arc of opening (i.e. anterior guidance) should be harmonious with condylar guidance. All theories of occlusion agree that cuspal interference and mandibular deviation cause muscular conflicts and may lead to dysfunction. Balancing side cuspal interferences, often associated with tipped teeth due to extractions, are believed to be a cause of TMD with joint clicking.

The general relationships between malocclusion and TMD are tenuous at best. Many studies have found no consistent relationship between morphological malocclusions and TMD. Egermark-Eriksson et al (1983) concluded that functional interference is more important than morphological malocclusion in the etiology of TMD. Epidemiological evidence weakens the general case that malocclusion causes TMD. However, TMD is more likely to be encountered in the presence of lateral interferences associated with crossbite or tipping of teeth. There is also an association between anterior open bite and TMD but care should be exercised in concluding that the relationship between openbite and TMD is only a matter of poor occlusal function. Clinical experience and the persistence of some openbite problems suggests that TMD and openbite have a poorly understood common muscular etiology.

The temporomandibular joint is a complex diarthrodial joint and its efficient function requires coordination of teeth, muscles and the articular disc. The functional activities involving this joint include speech, swallowing, respiration, mastication and habit activities. The cranio-cervical muscle groups do not cease activity at rest. In the resting phase, such as sitting upright in a chair, muscle groups enter a phase of balanced minimal activity. This maintains posture. As posture changes, the relative activities of the muscle groups change. The muscles attached to the mandible are part of this musculo-skeletal system. The occlusion of the teeth provides an additional proprioceptive input which influences the activities of the controlling muscles. A coordinated harmonious relationship between muscle groups and the teeth is the basis of a healthy, symptomless temporomandibular joint. Occlusal interference and abnormal joint function may cause temporomandibular dysfunction including joint tenderness and sounds, muscle tenderness, limited or deviated opening and headache. Headache alone is not a reliable indicator of TMD and it is doubtful that the dentist should undertake treatment if it is the sole presenting symptom.

Coordinated function of the muscles of the mandible is important in the treatment of temporomandibular joint dysfunction. Cuspal interference is one initiator of asynchronous muscular activity leading to dysfunction. Of great importance in

orthodontic treatment is the assessment of displacement of the mandible on closure to centric occlusion. Cuspal interference may cause a displacement of the mandible to the right, left or anterior direction. In the young developing patient, the teeth establish centric occlusion in this displaced position. The analogous situation would occur in prosthetics if we were to take a fully adjustable articulator and move one 'condyle' out of its socket and then construct a set of dentures in this false position. The teeth might appear to occlude correctly while the 'condyle' is displaced but once the 'condyle' is allowed to return to the normal position, occlusion of the teeth on the dentures would appear quite abnormal. So it is with the natural teeth if a patient must displace the condyles every time the teeth are occluded in order to achieve intercuspation.

The relationship between TMD and orthodontic treatment has been extensively studied by cross-sectional investigations of treated cases compared with untreated controls. The results have been almost totally negative (Sadowsky and Polson, 1984). However the longterm effects of orthodontic treatment on the occlusion are not totally understood and the study by Sullivan et al (1991) showed that orthodontic treatment substantially reduces the number of tooth contacts in the short term. Although the number of contacts gradually increases during and after retention, the number of occlusal contacts is significantly reduced up to nine years after treatment.

MANDIBULAR DISPLACEMENTS

Anterior displacement of the mandible may be initiated by aberrant eruption of a single anterior tooth into a position of incisal conflict which causes the mandible to protrude slightly in closing to centric occlusion in order to avoid the conflict. This places the tooth in crossbite relationship. In Class III malocclusions all the upper incisors may be in crossbite. Similarly lateral displacement of the mandible may occur due to cuspal conflict caused by a single aberrant tooth or by more generalised narrowing of the upper arch. Occasionally the mandible may deviate in both anterior and lateral direction. The end result in all instances is a difference between the retruded contact position and the intercuspal position (centric occlusion) (Fig. 12).

The principles of treatment are the same for lateral and anterior crossbites - namely, elimination of the interferences. For lateral crossbites this usually requires expansion of the arch to achieve correct buccal interdigitation. Anterior crossbites usually require labial movement of one or more upper anterior teeth to eliminate the interference causing any displacement. In more severe cases, some lingual movement of lower anterior teeth may also be required. Where the underlying problem is a severe skeletal discrepancy, orthognathic surgery will be required.

Posterior mandibular displacement (posterior displacement of the condyle in the fossa) may supposedly occur in patients with a very deep overbite as commonly found in Class II division 2 malocclusions but the supporting evidence for true posterior displacement in the fully dentate subject is arguable.

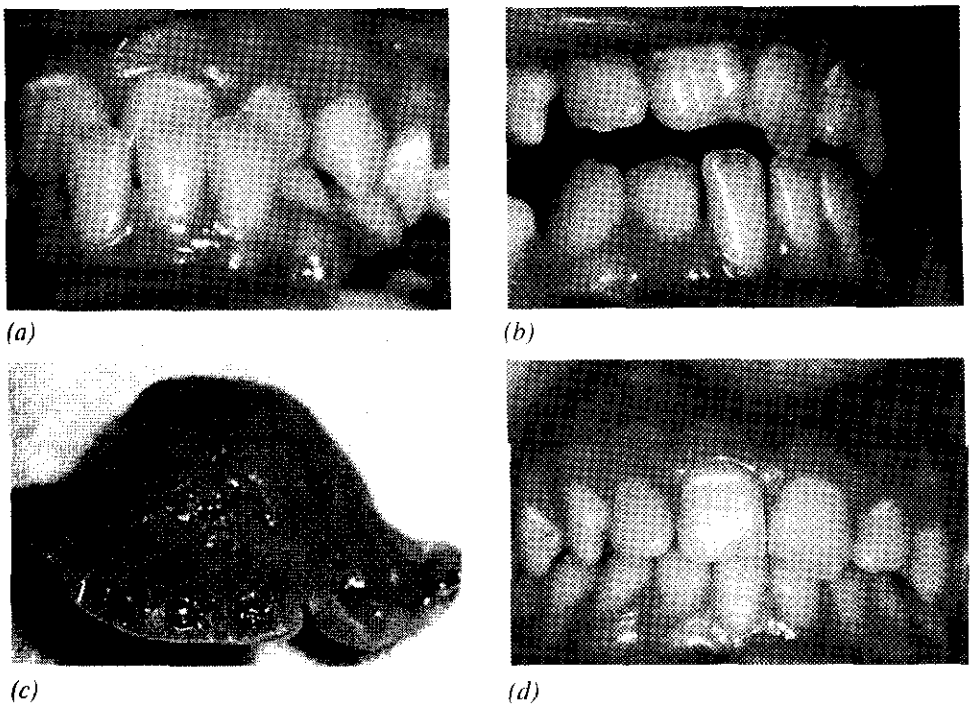


Fig. 12: (a) Reverse overjet with forward displacement of the mandible to centric occlusion (b) True fully retruded position of the mandible with edge to edge incisor contact (c,d) Treatment by means of a removable appliance to procline the upper incisors achieved a normal occlusion.

FUNCTION AND STABILITY

Stability of the occlusion is a relative term and does not imply an unchanging occlusion until the ultimate demise of the teeth or their owner. We expect certain changes to occur naturally with ageing, and in societies without marked interproximal wear, crowding of the lower incisors is considered to be natural. Where orthodontic treatment has been undertaken, unusual efforts may be required to maintain the corrected relationships even to the point of semi-permanent retention in rare cases. The eruption of third molars is one of a series of factors causing change. It is difficult to prove unequivocally the role of third molars in crowding simply because of the wide variation in other conditions which may exacerbate or compensate for the effects of third molars. The availability of space for the development of third molars is now well documented, although not a widely recognised clinical feature of occlusal development. It can be demonstrated that extraction of premolars results in a greater proportion of erupted third molars. It is well known that the eruption of third molars is associated with the appearance of incisor crowding in young adults who then seek treatment for the crowding and malalignment. Whether this association is causal or coincidental has been the subject of research over many years.

Similarly, the effects of mandibular occlusal function on long-term occlusal stability are not well documented but there is evidence to suggest that abnormal patterns of function may be another link in the chain of environmental factors leading to destabilisation of the occlusion and subsequent occlusal changes. This seems to be particularly true in the event of loss of supporting posterior teeth contributing to drifting of adjacent and opposing teeth. An associated non-specific periodontal condition is often implicated. It may be that abnormal functional contacts and the loss of teeth as well as a compromised periodontal condition of the remaining teeth causes an alteration in the force-duration equation thus leading to drifting of the anterior teeth within an altered zone of balance.

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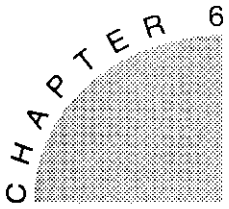
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DEVELOPMENT OF OCCLUSION

For practical purposes, development of the occlusion may be divided into three continuous stages. The deciduous dentition stage begins soon after birth and is completed with the eruption of all the deciduous teeth. The mixed dentition stage beings with eruption of the first permanent molars. The adult dentition stage then commences with the loss of the last deciduous tooth.

DECIDUOUS DEVELOPMENT

The deciduous teeth commence formation 'in utero' and at birth the infant is usually edentulous although the gum pads show early signs of development of the teeth. Deciduous eruption begins with the lower central incisors. The ages of eruption may be quite variable. In some cases the lower deciduous incisors have erupted at birth, making breast feeding difficult. Normally the newborn infant is edentulous for about six months during which time the developing gum pads provide the framework for suckling and swallowing with the tongue playing an active role.

The upper gum pad is horseshoe shaped and the palate is flat and shallow. The gingival groove separates the developing palate from the developing alveolus. Both upper and lower gum pads are segmented by transverse grooves which correspond to the developing deciduous teeth and the grooves distal to the developing canines are more pronounced. The lower gum pad is more U shaped than the upper and the lateral regions have a relatively narrow edge compared to the anterior region which is fuller and everted. At rest the gum pads do not meet and the tongue lies between them (Fig. 1). In function the gum pads contact frequently in the posterior regions with a vertical space persisting in the anterior region — this space disappears as the incisors erupt. There is a definite antero-posterior relationship of the gum pads which can be judged by the grooves distal to the developing canine segments. The lower canine groove lies distal to the upper canine groove. Various relationships of the gum pads may ultimately develop into normal occlusion.

Usually the lower teeth erupt before corresponding upper teeth. Note that the deciduous first molar erupts before the canine. The roots of the deciduous teeth normally have completely calcified by about 3 years of age. All deciduous teeth have normally erupted by two and a half years of age. The order of eruption is incisors, first molars, canines, second molars with lower teeth preceding the upper teeth.

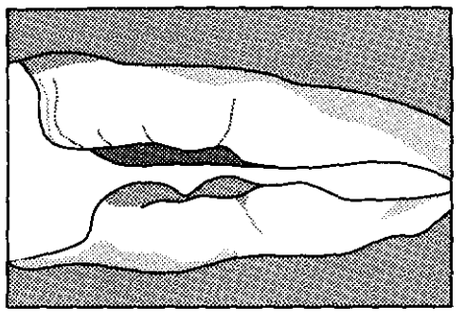


Fig. 1: Gum pads in the new born child show grooves corresponding to the developing deciduous teeth.

NORMAL DECIDUOUS ARCHES

The normal deciduous arches are ovoid in shape. Inter-dental spacing of the deciduous arches may range from no spacing (closed arch) to spacing between every tooth. Commonly, there are spaces between the incisors (Fig. 2). Spaces between the upper lateral incisor and canine and between the lower canine and first molar are regular features of the normal deciduous dentition and have been termed the primate spaces. It is desirable that there be spacing in the arches at the stage of completion of the deciduous dentition. Baume (1950) has reported that spacing of the incisors is either present or absent and the situation does not change until the permanent incisors begin to erupt.

Spacing in the deciduous molar areas is less common and tends to close with development, particularly with commencement of the eruption of the first permanent molars. Not infrequently we may see children with little or no spacing of the deciduous teeth other than the primate spaces. While we cannot say definitely that crowding of the permanent dentition will result, it is a warning sign. A favourable growth response or abnormally small teeth may compensate for an apparent lack of space in the deciduous dentition. Basically the dimensions of the deciduous arches change little between the stage of completed deciduous eruption and the eruption

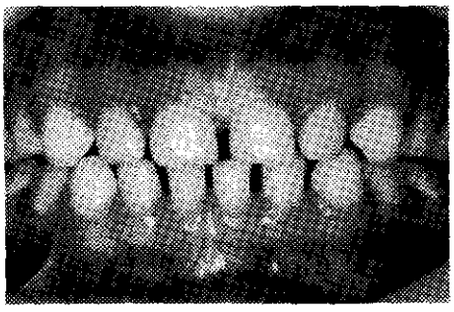


Fig. 2: Class I deciduous dentition with spaced incisors – centre lines are not coincident.

of the first permanent molars, from approximately 2.5 to 6 years of age. Another feature of the deciduous dentition during this time has been frequently noted. That is, substantial occlusal wear associated with forward shift of the whole lower arch. This reflects a relative forward growth of the mandible. It does not occur in all cases and some children may show little occlusal wear of the deciduous teeth (Figs. 3).

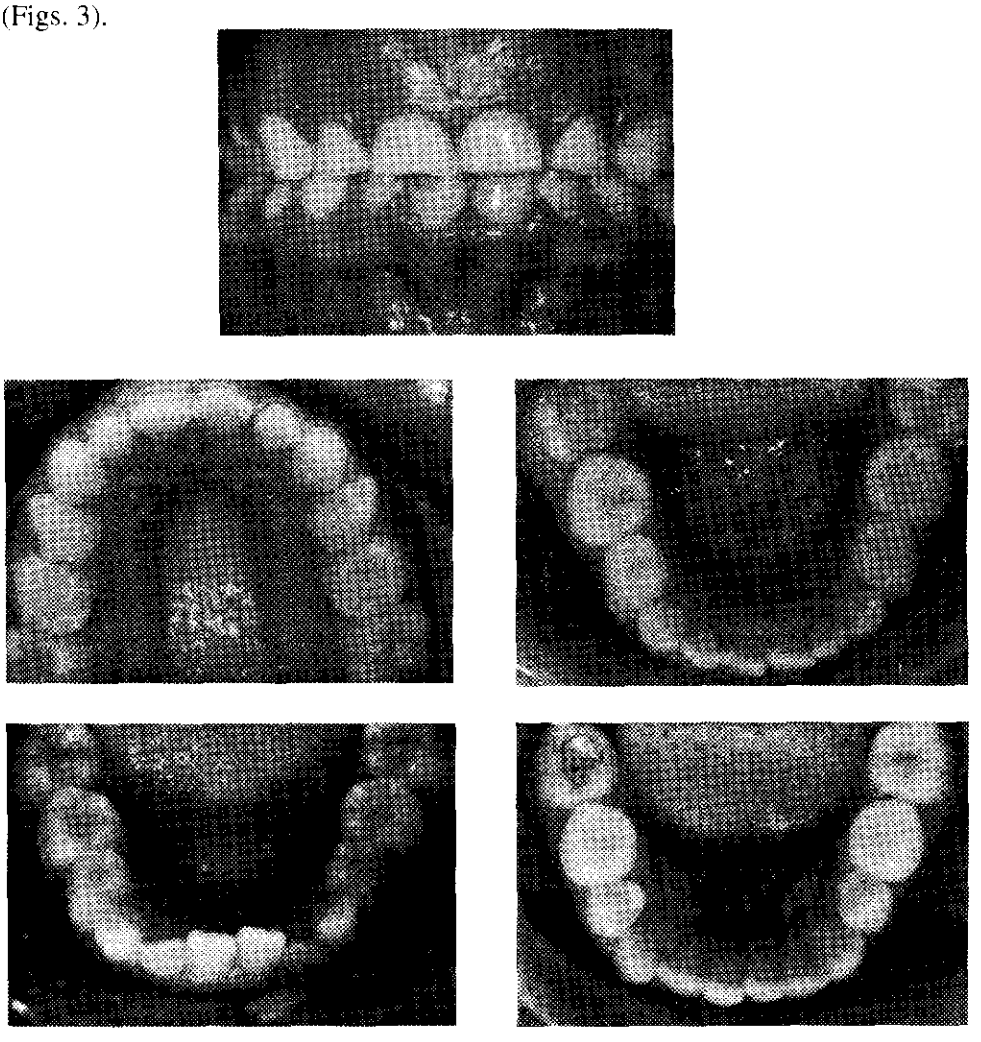


Fig. 3: Deciduous dentition without spacing of the incisors. The occlusion also shows considerable wear. The lower two photographs show the same lower arch 1 year and 3 years later.

DECIDUOUS ARCH RELATIONSHIPS

Terminal Plane

Arch relationships of the deciduous teeth should fall within certain limits if they are to be considered normal. Much the same cusp-embrasure relationships apply in the

normal deciduous dentition as in the normal permanent dentition. The mesiobuccal cusp of the upper second deciduous molar occludes near or in the buccal groove of the lower second deciduous molar. The upper canine tip occludes near or in the lower primate space. Where occlusal wear is marked, these inter-relationships may become less easily identified particularly on study models, suggesting the need for accurate bite registration when study models are obtained.

The relationships of the distal surfaces of the upper and lower second deciduous molars have been widely studied and two types of relationship are considered to be normal. The mesial step reflects a step forward from the distal of the upper second molar forward to the distal of the lower second molar. This is essentially the same relationship that pertains between the distal surfaces of the first permanent molars in normal occlusion. The flush terminal plane is also considered by some to be normal, reflecting a relatively large lower deciduous molar width. In this case the distal surfaces of the upper and lower second deciduous molars lie in the same vertical plane (Fig. 4).

In both instances, normality of the occlusion will be reflected in the normal relation of the upper canine to lower canine with the upper canine tip lying in the embrasure distal to the lower canine. The difference between the mesial step and flush terminal plane relationships is that the flush terminal plane will initially guide the first

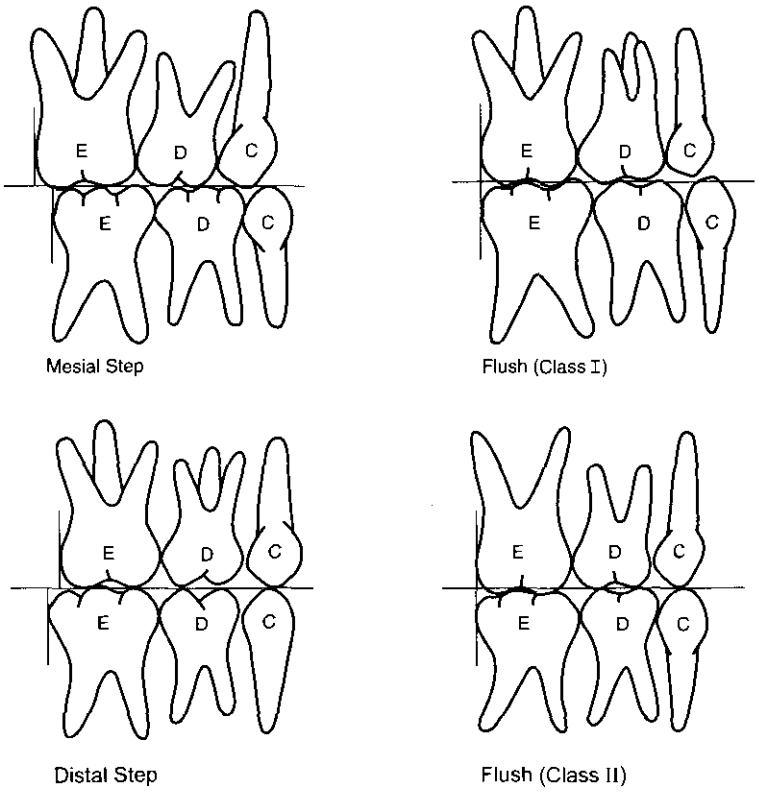


Fig. 4: Terminal plane relationships of the second deciduous molars.

permanent molars into an end-to-end relationship, which should adjust on exfoliation of the deciduous second molars, while the mesial step will allow eruption directly into the normal cusp-groove position.

The difficulty is that many flush terminal plane relationships are not normal and represent an incipient Class II malocclusion. This is easily checked. Careful examination of the canine relationships will show that the Class II tendency is also visible in this region with the canine relationship being more end-to-end rather than the upper canine tip lying in or over the lower primate space. A flush terminal plane in association with a end-to-end canine relation is indicative of a developing Class II occlusion. A distal step relationship is seen where the distal surface of the lower second deciduous molar lies distal to that of the upper second deciduous molar. In this instance it is expected that the permanent molars will erupt directly into a distal or Class II relationship which will not usually change.

Bishara et al (1988) studied the effects of different deciduous terminal plane relationships on the ultimate first molars relationships. Distal step relationships were found in only 9.5% of the sample and all progressed to a full or partial Class II relationship of the first permanent molars. A flush terminal plane was found in 29% of cases of which 56% became Class I and 44% became Class II. The same study found a mesial step of 1 mm in 42% of cases of which 76% became Class I, 23% became Class II and 1% became Class III. A mesial step of 2 mm was found in 19% of the total of which 68% became Class I, 13% became Class II and 19% became Class III (Fig. 5). In spite of the commonly held belief that leeway space is the most important adjustment mechanism in the attainment of Class I molar relations they found no correlation between first permanent molar adjustment and the difference between the upper and lower leeway space – the lower leeway space being larger should allow for greater forward movement of the lower molar.

These findings highlight the complexity of development of the occlusion and underline the fact that the ultimate attainment of a normal buccal occlusion is not necessarily assured by any particular arrangement of the second deciduous molar distal surfaces although the probabilities are much better with the mesial step relation. Loss of the second deciduous molars is a critical stage particularly where there is any tendency to a retrognathic skeletal pattern which will more naturally guide the teeth into a Class II pattern. As with most situations requiring effective monitoring, sensible decisions can only be made on the basis of accurate information which should include adequate records such as study models and x-rays. Occlusal guidance without the necessary records is unlikely to engender sensible decisions.

The space available in the deciduous arches (arch circumference) is normally not quite sufficient to accommodate all of the permanent teeth anterior to the first permanent molars. The deciduous canine, first molar and second molar are wider than the permanent successors giving rise to the term leeway space. However, the total width of the permanent incisors is greater than the total width of the deciduous incisors, the difference being termed the incisor liability. The incisor liability is

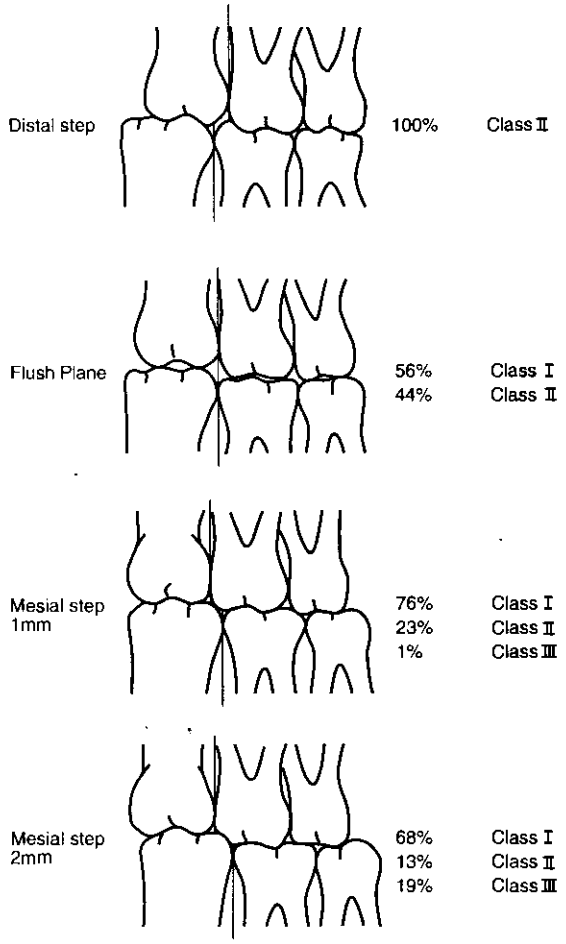


Fig. 5: Percentages of Class I, Class II, and Class III permanent molar relationships resulting from different terminal plane relationships of the second deciduous molars.

slightly greater than the leeway space leading to a net arch space deficit. Therefore extra space must be found for alignment of all the permanent teeth, particularly the incisors. Research also raises considerable doubt about the usefulness of average values in assessing the development of the dentition. Previous estimates of upper and lower leeway space have varied considerably although the values proposed by Moyers (1973) are widely used for mixed dentition analyses – 1.7 x 2 mm in the lower segments and 0.9 x 2 mm in the upper segments (Fig. 6, 7).

Steigman et al (1982) found that in a few cases the leeway space may be a small negative value with the sum of the canine and bicuspid widths actually exceeding the deciduous widths. However they found an average value of about 0.9 mm per side in the upper segments and 2.0 mm per side in the lower segments. Importantly, they found a range of -2.5 to +3.5 mm in the upper and -0.5 to +4.7 mm in the lower. Thus rare cases may have as much as 9 mm or so of leeway space in the lower arch. They concluded that the transition to the adult molar relationship is

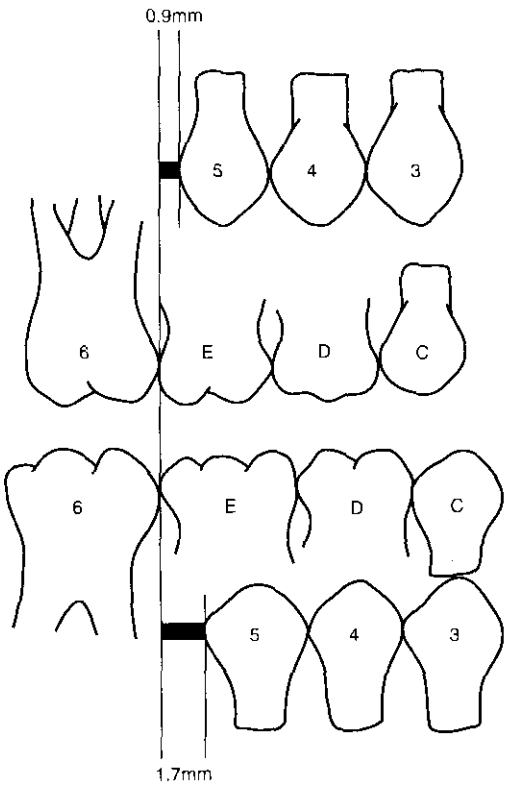


Fig. 6: Average values for leeway space in the upper and lower arches.

affected by processes of differential maxillary and mandibular growth as well as by local changes within the dental arches. Individual tooth size assessments are highly recommended in preference to average or predicted values. Where space analysis is required in the borderline case, reliance on average predicted values makes little sense.

The incisor liability (Fig. 7) may be compensated as follows:

1. Inter-canine arch width increase as the permanent incisors erupt
2. Smaller than expected permanent teeth
3. Encroachment posteriorly into the leeway space (Fig. 8)
4. A more labial position and angulation of the permanent incisors

Overbite in the deciduous dentition may be relatively deep in the early stages but with occlusal attrition the overbite reduces between 3 and 6 years of age. The deciduous incisors are more upright compared to their permanent successors. Overbite in the deciduous dentition is not a reliable predictor of overbite in the permanent dentition. Moorrees (1959) found that overbite is highly variable and there is no reliable predictive relationship between the deciduous and permanent overbite values.

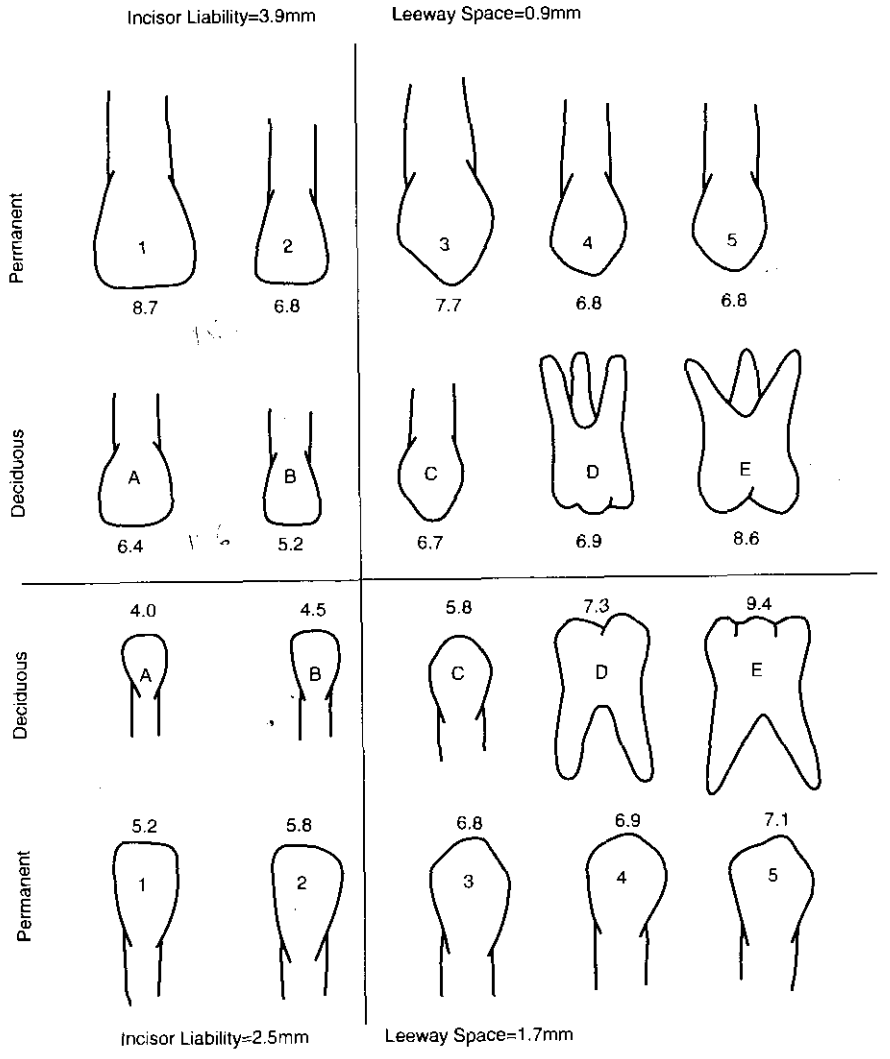


Fig. 7: Average deciduous and permanent tooth widths.

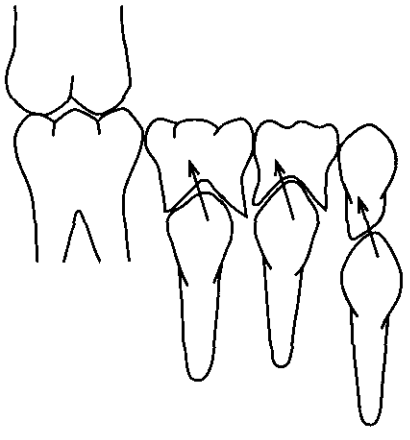


Fig. 8: Partial utilisation of the leeway space by upward and backward eruption of the canine and biscuspids.

MIXED DENTITION STAGE

This stage begins with eruption of the first permanent molars at about 6 years of age. It is a period of continuing change which lasts until the last deciduous tooth exfoliates. Just prior to and during eruption of the first permanent molars, any natural posterior deciduous spaces tend to close from behind. Arch circumference, therefore, may actually reduce slightly at this time.

A common method for estimating leeway space is the prediction table. This is based on the size relationship between anterior and posterior teeth, the general hypothesis being that the larger the combined widths of the four lower incisors, the larger will be the combined widths of the upper and lower canines and bicuspids. This prediction may be made with varying degrees of probability or accuracy. The aim is to select a level of probability which is better than a simple rule of thumb. On the other hand, if too high a level of probability or accuracy is used, the number of predictive intervals will be unnecessarily large and the table will be unmanageable. The 75% level of Moyers is given (Table 1).

SUM $\overline{21\|12}$	SUM $\overline{3\,4\,5}$	SUM $\underline{3\,4\,5}$
19.5mm	20.1mm	20.6mm
20.0mm	20.4mm	20.9mm
20.5mm	20.7mm	21.2mm
21.0mm	21.0mm	21.5mm
21.5mm	21.3mm	21.8mm
22.0mm	21.6mm	22.0mm
22.5mm	21.9mm	22.3mm
23.0mm	22.2mm	22.6mm
23.5mm	22.5mm	22.9mm
24.0mm	22.8mm	23.1mm
24.5mm	23.1mm	23.4mm
25.0mm	23.4mm	23.7mm
25.5mm	23.7mm	24.0mm
26.0mm	24.0mm	24.2mm
26.5mm	24.3mm	24.5mm
27.0mm	24.6mm	24.8mm

Table 1: Moyers prediction table (75% level)

The user simply calculates the combined widths of the lower four permanent incisors then reads across to obtain the probable sum of the widths of the canines and bicuspids in the upper and lower arches respectively. It should be noted that the prediction table method will often be inaccurate and the only way to guarantee accuracy is to calculate the widths of the unerupted teeth from x- rays sucb as bite wings, making allowance for magnification.

$$\frac{\text{X-ray width of second deciduous molar}}{\text{Actual width of second deciduous molar}} = \frac{\text{X-ray width of unerupted tooth}}{\text{Actual width of unerupted tooth}}$$

For example if the width of the lower second deciduous molar in the mouth and on x-ray is 9.5mm and 11mm respectively and the width of the second bicuspid on the x-ray is 8mm then estimate the true width of the bicuspid as follows:

$$\left(\frac{9.5}{11}=\frac{x}{8}\right) \qquad x=\frac{8\times 9.5}{11}=6.9 \text{ mm}$$

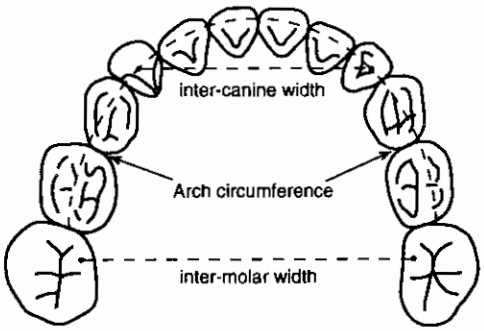


Fig. 9: Definition of measurements of arch dimensions: inter-canine width, arch circumference and inter-molar width. (Redrawn from Moorrees CFA, 1959.)

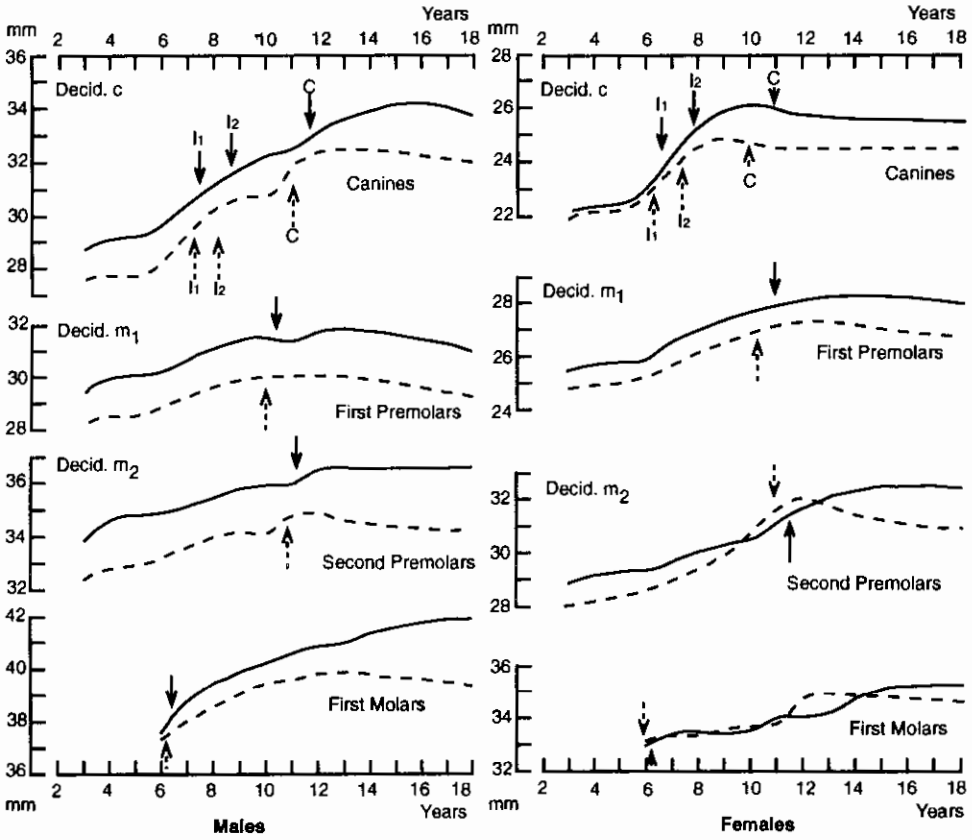


*Fig. 10: Changes in arch width dimensions from the deciduous dentition to 18 years of age. (Redrawn from Moorrees, CFA : **The Dentition of the Growing Child**,* Harvard University Press, Cambridge, 1959.)

MOLAR ADJUSTMENT

Should the first permanent molars erupt in an edge-to-edge relationship due to the existence of a flush terminal plane, a normal cusp-groove Class I relationship may be established subsequently in several ways. There may be slight continued relative forward migration of the whole lower arch associated with growth of the mandible as well as forward adjustment on exfoliation of the second deciduous molars. The larger leeway space in the lower arch allows further forward migration of the lower first permanent molar. The order of deciduous tooth loss in the upper and lower arches may influence this adjustment. Preferably the lower second deciduous molar should be lost before the upper second deciduous molar, so that the lower first permanent molar moves forward before loss of the upper deciduous tooth. In borderline cases, loss of the upper tooth first might establish a Class II relationship.

INCISORS AND CANINES

Permanent incisor eruption begins with eruption of the lower incisors soon after the first permanent molars at about 6 years of age, followed by eruption of the upper incisors. This is a stage of relatively rapid change in arch shape and dimensions. The permanent incisors must finally overcome the incisor liability by an increase in inter-canine dimensions and at this late stage, spacing between the deciduous incisors may increase slightly. With the eruption of the incisors there is also an increase in the antero-posterior dimension (arch depth) because the permanent incisors not only erupt to a slightly more anterior position than the deciduous incisors but are also more proclined. These effects are particularly noticeable in the upper arch where the edges of the permanent incisors are up to 2mm further forward than their deciduous counterparts, while in the lower arch they are about 1mm further forward.

The work of Moorrees (1959) has documented the expected changes in arch dimensions at various stages of incisor and canine eruption (Figs.9,10). Several points should be noted. On average the inter-canine widths increase gradually from the time of eruption of the deciduous canines with relatively greater increases occurring during eruption of the permanent incisors and canines. The increase in the upper canine width is slightly more prolonged than the lower canine width increase. After complete eruption of the canines there is little change in inter-canine widths, although in males a further small increase might be expected during the puberal growth spurt, although of limited practical use. The premolar widths increase slightly from the equivalent deciduous tooth widths. Molar widths, particularly in the upper arch, continue to increase up to about 18 years of age but the increase is limited. Arch circumference in the upper arch remains about the same on average with a small increase in the upper arch circumference in males. Lower arch circumference in both males and females can be expected to decrease significantly between 5 years and 18 years in spite of any other dimensional changes that may occur at the same time (Fig. 11).

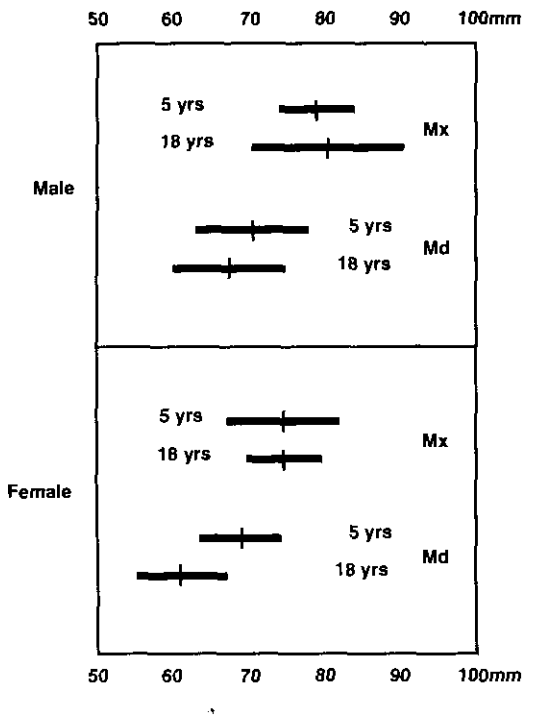


Fig. 11: Means and standard deviations of measurements of arch circumference in upper and lower arches for males and females at 5 years and 18 years. (Redrawn from Moorrees, 1959.)

Moorrees et al (1969) highlighted the importance of individual variation from these mean values but from a practical viewpoint there are no reliable predictors of individual performance and the clinician is only able to judge according to the mean values. The most important conclusion from this research is that the dimensions of the dental arches anterior to the first permanent molars can be expected on average to change relatively little after eruption of the permanent teeth. Orthodontic expansion to gain space can be expected to be unstable over the long term.

UGLY DUCKLING STAGE

The term ugly duckling stage has been used to highlight the positions of the incisors due to the erupting canines. The permanent incisors lie lingual to the deciduous incisors before eruption and on x-ray may appear crowded. In some cases the incisors, particularly in the lower arch, actually erupt in this crowded position before final alignment. Occasionally, the upper lateral incisor will continue to erupt in an extreme lingual position. The upper central incisors commonly erupt with a diastema between them which may close partially on eruption of the lateral incisors. The lateral incisors may erupt with a slight distal inclination. This may increase noticeably during the early stages of eruption of the canines due to pressure on the distal aspects of the incisor roots causing distalisation of the crowns (Figs. 12,13).

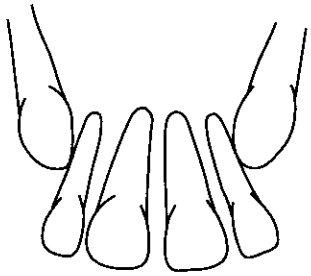


Fig. 12: Eruption of the permanent canines against the distal surfaces of the roots of the lateral incisors during the ugly duckling stage.

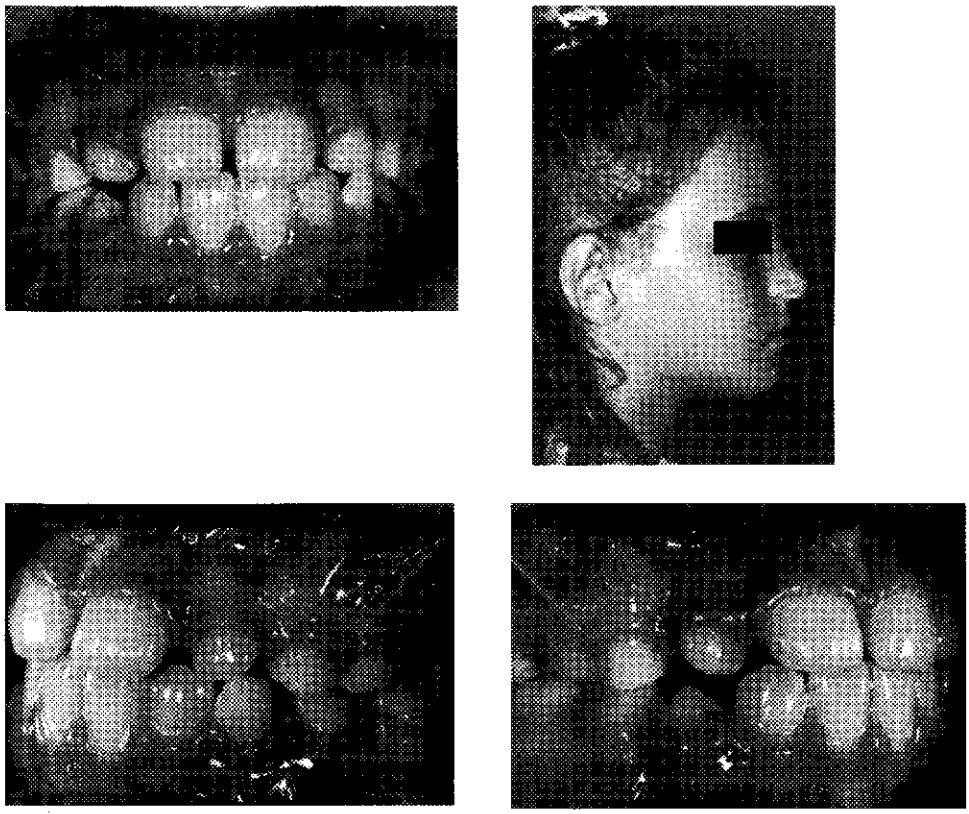


Fig. 13: Class I mixed dentition with normal buccal segment relations. The upper lateral incisors are distally inclined due to the erupting canines. The canines should be checked.

The ugly duckling stage is transient and should disappear with complete eruption of the canines causing final approximation of the crowns of the incisors. The real importance of the ugly duckling stage lies in assessing the position and angulation of the permanent canines because it is at this time that the canine may become displaced palatally after sliding behind the lateral incisor root. Less frequently the canine may continue to erupt forward labially over the lateral incisor. Unusual angulations of the lateral incisors should always be suspected as being potentially abnormal.

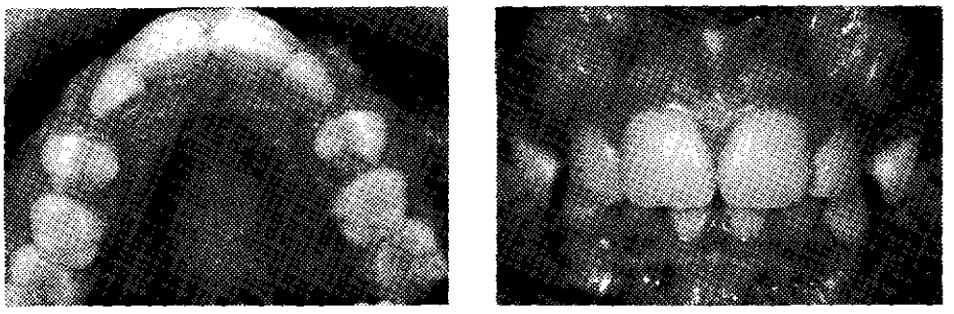


Fig. 14: Developing crowded dentition with the upper canines apparent as bulges above and buccal to the upper lateral incisors.

Two cardinal rules of examination should be observed. Look for the bulge of the canine crown in the buccal sulcus (Fig. 14) and check the angulation of the erupting canine on x-ray. This is most easily done on an OPG or its equivalent. The OPG has one particular quality for this purpose – because it gives a barrel projection of all the teeth, their relative angulations are clearly visible. Should an abnormal angulation of the canine be suspected or should it appear to superimpose over the lateral incisor root, then follow-up is required (Fig. 15).

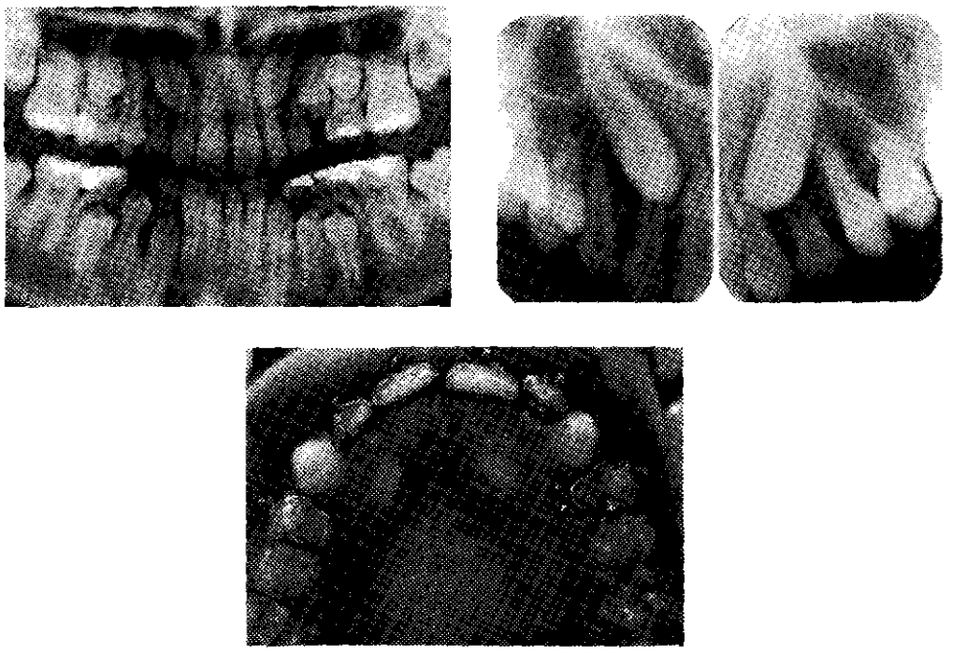


Fig. 15: The OPG shows the upper canines lying too far mesially over the lateral incisors. The poor positions and angulations are confirmed on the periapical x-rays. The clinical photograph shows the positions in which the canines erupted with the deciduous teeth being retained.

CLINICAL CONSIDERATIONS

1. Shortage of space, usually gross, at the early age of eruption of the first permanent molars, may lead to impaction of the first permanent molars under the distal aspect of the deciduous second molars. This is one of the most distinctive early signs of incipient crowding. This condition causes early resorption of the distal root of the deciduous molar and usually requires interceptive treatment to disimpact the first permanent molar. Extraction of the second deciduous molar may be necessary on occasions followed by secure space maintenance (Fig. 16).

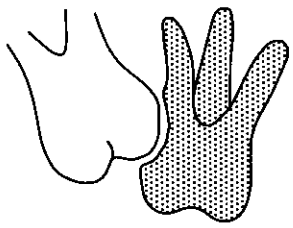


Fig. 16: Ectopic eruption of the upper first permanent molar causing resorption of the second deciduous molar.

2. Early exfoliation of the deciduous canine on one side caused by eruption of the lateral incisor is a warning sign of crowding and is usually associated with a significant centre line shift to the side where the loss occurred.

3. Continued space shortage in the incisor region after complete eruption of the permanent lateral incisors may suggest implementation of a serial extraction procedure if the crowding is substantial and the other conditions for serial extraction are satisfied.

4. Prognosis is better where there is spacing present in the deciduous dentition but up to 40% of closed deciduous arch cases may go on, through growth, to develop a normal permanent occlusion.

5. After complete eruption of the permanent canines, none of tbe arcb dimensions changes very much on average and assessments of crowding/spacing after this time can be made more confidently.

6. Gingival recession on the labial surface of a prominent lower incisor may signify an inherent crowding problem with labial displacement of one incisor. However there is usually an associated high attachment of the labial frenum and a poor toothbrushing technique which contribute to the problem. With conservative maintenance the problem usually resolves although rare cases require more complicated periodontal treatment (Fig. 17).

7. Vertical stacking of the upper molar teeth on the OPG x-ray is a further sign of posterior arch length inadequacy and a warning against distal arch expansion to accommodate crowded anterior teeth.

PERMANENT DENTITION

The stage of the permanent dentition begins with exfoliation of the last deciduous tooth. This may overlap with eruption of the second permanent molars, usually occurring at about 12 years of age. In general, females reach the adult dentition stage slightly earlier than males but the difference in dental ages is usually not as marked as the difference in skeletal or physiological ages. One of the most important aspects of permanent tooth eruption is the wide variation in the timing of eruption. Eruption of bicuspids and canines as late as fifteen years is seen relatively frequently. Family history is often indicative and the problem may affect several children in the same family. Orthodontic treatment may be prolonged until the bicuspids are ready to erupt, particularly where permanent extractions are to be carried out. The delay may mean that the patient enters the later grades of high school during treatment.

SPACE ANALYSIS

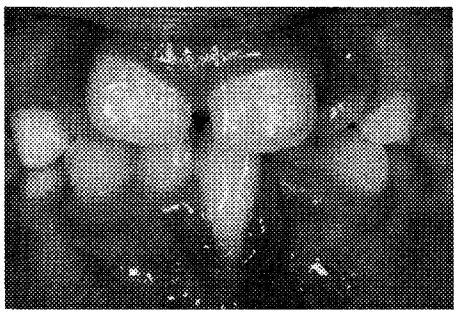
The mixed dentition space analysis is a static analysis of the space available in the mixed dentition arch for eruption of the permanent teeth. At the usual stage of mixed dentition analysis the only permanent teeth which have erupted are the first permanent molars and the incisors. An estimate of the widths of the unerupted canines and bicuspids must be made. Space available is the arch circumference measured around the arch between the mesial contact points of the first permanent molars. Arch circumference may be measured with a pair of callipers as the sum of four segments from mesial of first permanent molar to distal of the lateral incisor to the mesial contact point between the two central incisors. The sum of the four segments (A+B+C+D) represents the space available (Fig. 18). Unfortunately this method is subject to significant error when the anterior teeth are imbricated and the choice of landmarks is problematical.

The better method for estimating arch circumference is to measure the line of best fit on a photocopy of the occlusal arch form. This is the line of the arch circumference through the existing contacts. Where imbrication is present the estimated line of best fit is averaged between the crowded teeth making sure not to 'expand' the arch line. All estimates of arch circumference are subject to variation. The length of the line of best fit (Fig. 19) may be measured with a good pair of dividers by setting the dividers at a reasonably small value (e.g. 5 mm) and stepping round the line to calculate the length. Any small remaining fraction is measured and added to the total number of steps.

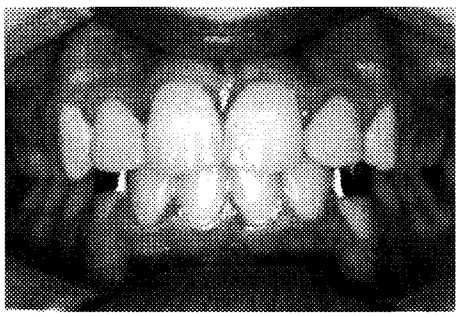
The space required is that space to be occupied by all of the permanent teeth anterior to the first molars. The widths of the four incisors may be measured directly. The widths of any unerupted canines and bicuspids will have to be estimated either on x-ray or using the prediction table of Moyers. As previously pointed out the prediction table will necessarily be inaccurate on occasions and the width of the unerupted teeth can only be estimated accurately by means of intra-oral x-rays. The widths of



(a)



(b)



(c)

Fig. 17: (a) Labial recession on the lower left central incisor associated with a high frenal attachment. (b) Labial damage on lower left central incisor associated with poor tooth brushing technique and high frenal attachment. (c) Same patient five years later after orthodontic treatment.

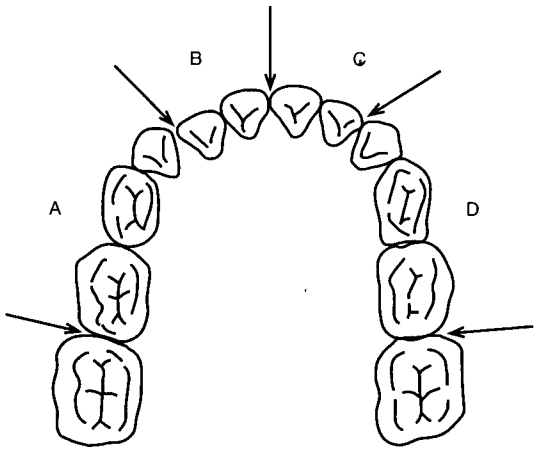


Fig. 18: Segments defining the four sections of the dental arch. These are added to provide an estimate of arch circumference from one permanent molar to the other.

unerupted teeth are calculated from the magnification of the erupted teeth on the same x-ray (Fig. 20). In a child with a small mouth it may be difficult to show all the canines and bicuspids on the x- rays. In this case calculate the true widths of the teeth that are shown on the x- rays. Then use these as a check of the accuracy of the

values obtained from a prediction table. While all teeth may appear on an OPG x-ray, the magnification on an OPG is not reliably calculated in most instances.

The final mixed dentition analysis is simply performed by subtracting the space required (sum of tooth widths) from the space available (arch circumference). Note particularly that the calculated space available includes the leeway space. Because the permanent incisors have erupted, any anterior arch growth which will help compensate for the incisor liability will already have occurred. No further significant increase in anterior arch dimensions can be expected although a further small increase may occur on eruption of the permanent canines. Thus after eruption of the permanent incisors the spacing/crowding estimate is not altered by the presence of the leeway space which has already been included in the space available measurement. If there is an excess of space available over space required and the incisors are slightly crowded, then the excess might be utilised to align the incisors by fitting a lingual holding arch which prevents the forward migration of the molars when the deciduous teeth are lost. If the crowding is substantial then permanent extractions might be required. Then the extra space made available with the extractions will include the width of the two bicuspids (e.g. 14 mm). Thus the leeway space may be 'discarded' but it cannot be used to increase the space available.

Where permanent extractions are to be performed then the leeway space will be lost automatically as part of the space closure after extractions. Much confusion arises from the utilisation of the leeway space component of the mixed dentition space analysis. Some clinicians believe that the leeway space is always ultimately lost by forward migration of the first permanent molars irrespective of any efforts to hold it with a space maintainer although this would seem to be an extreme view. The clinician must decide at this time whether to allow leeway space loss with forward molar adjustment (Fig. 21). However, if for other reasons it is decided that lower arch extractions are not acceptable and all the leeway space will be used to align crowded incisors, then forward movement of the lower molar will be prevented. Note also that if the molars are presently not in a Class I relationship, the upper molar must be moved back to Class I.

The mixed dentition analysis in the lower arch is generally of much greater importance than in the upper arch. This is because the lower arch is the supporting template and a decision to extract in the lower arch is the governing decision. In addition, extraction in the upper arch only, may be made for reasons of convenience rather than space requirements, e.g. to overcome the need for headgear. A very important aspect of the mixed dentition analysis needs to be stressed. The analysis is static. It is made on the basis of the present state of the occlusion. The analysis only gives an indication of spacing or crowding in the arches as they stand at the time of examination. Such an analysis must not be used as the only indication of the need for extractions. It may be desirable to alter the lower arch in some cases particularly where the lower arch dimensions have been distorted by some external agency such as digit sucking and modification is therefore justified. This may provide the extra space to overcome any deficiency revealed by the mixed dentition analysis.

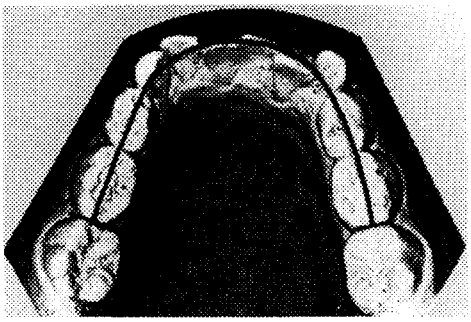


Fig. 19: Arch circumference line drawn on a photocopy and used to measure the space available for all teeth mesial to the first permanent molars.

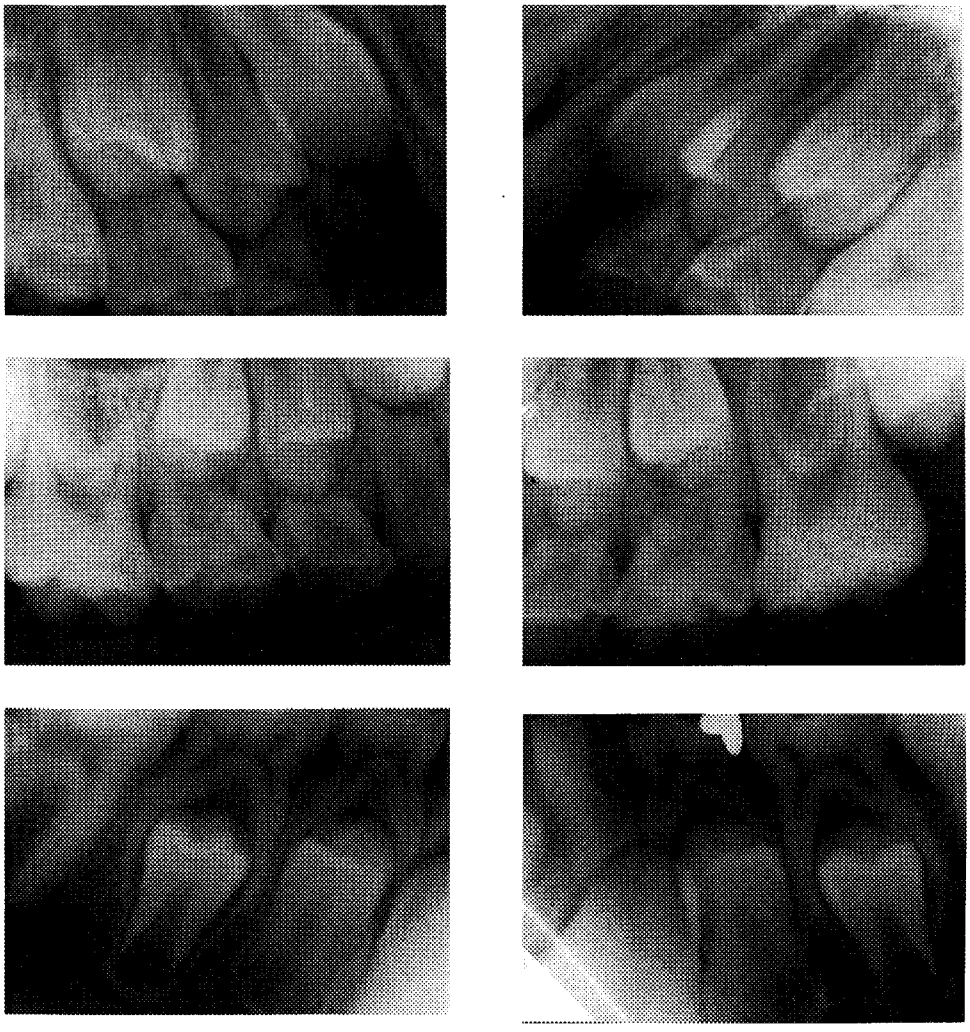


Fig. 20: Intra-oral x-rays of unerupted teeth used to calculate true mesio-distal widths. If all teeth are not visible then extrapolation from prediction tables must be done.

Mixed Dentition Analysis		Md	Mx
(1) Space available (arch circumference)	+ve		
(2) Space required (sum tooth widths)	–ve		
(3) Difference 1 and 2	+ ve or - ve		
(4) Forward molar adjustment allowed each side	zero or -ve		
(5) Total			

Fig. 21: Components of the mixed dentition analysis. Account must be taken of the positive and negative values.

The mixed dentition analysis is only one of several steps to be carried out before extracting teeth.

OVERALL ASSESSMENT OF SPACE

Having determined the amount of crowding in the arches using the mixed dentition analysis, we must now go on to determine the need for extractions. While "treating to the numbers" from a cephalometric analysis is to be avoided, we should be aware of the possible results of permanent extractions. Careful clinical examination will show the relationship of the lips to the face. A supra-mental groove may be present. Such factors ought to be considered when contemplating extractions. A useful indication of the position of the lower incisors in the profile is the distance of the lower incisal edge to the APo line on a cephalogram. A value less than – 4mm might suggest that lower incisor advancement should at least be considered, depending on the type of malocclusion, the amount of crowding present and the soft tissue outline. Forward movement of the lower incisors is rarely the method of choice for gaining arch circumference but occasionally extractions are patently undesirable and do not provide a reasonable alternative.

Every millimetre of forward movement of the lower incisors provides 2 mm of increased arch circumference (Fig. 22). Thus moving lower incisors from – 3 mm to 0 mm to the APo line provides an extra 6 mm of arch circumference. These procedures are used infrequently and only where extractions in the lower arch are absolutely contraindicated. Where the profile is already compromised or the lower incisors have fallen back it makes no sense to extract and exacerbate the problem. Thus a static mixed dentition analysis is not a sufficient basis from which to determine the need for permanent extractions either immediately prior to treatment or as part of a serial extraction program.

In other instances there may be an overfullness of the lips in the presence of minor crowding indicating a dento-alveolar protrusion. If so, extractions with retraction

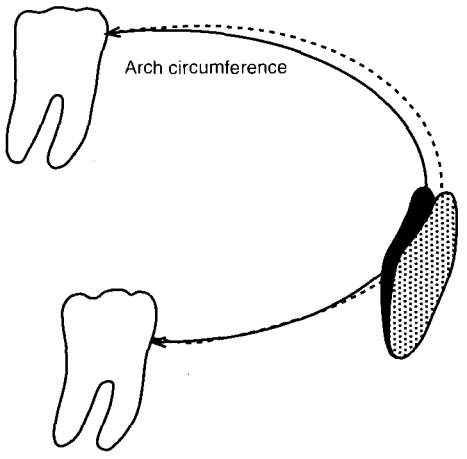


Fig. 22: Effect of lower incisor proclination causing an increase in arch circumference.

of the incisors may be strongly indicated to alleviate the crowding and to reduce the protrusion of the lips. This need can be conveniently determined from a lateral cephalogram as an adjunct to careful clinical examination. Retraction of the lower incisors will reduce the arch circumference and help to close extraction spaces. The overall space analysis is an integration of the static analysis derived from the mixed dentition analysis, space derived from any extractions and the further modification to be made from adjustment of the lower incisor position to the APo line (Fig. 23).

Overall Space Assessment		Mx	Md
1 Result of Mixed Dentition Analysis	+/–		
2 Arch circumference change (lower incisor × 2)	+/–		
3 Difference between 1 and 2 above	+/–		
4 Extraction space (2 bicuspids = 14 mm)	+/–		
5 Overall space excess or shortage	+/–		

Fig. 23: Components of the overall space analysis. Each section must be given a positive or negative value.

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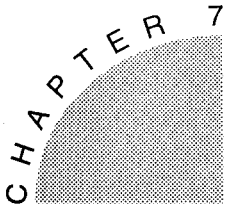
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OCCLUSAL RELATIONSHIPS

DEFINITIONS OF OCCLUSAL TRAITS

Occlusal assessment is based on a set of characteristics or traits, the definitions of which have been standardised for orthodontic purposes. In order to communicate information accurately it is important that the examiner be thoroughly familiar with the definitions and meanings of the occlusal traits. All definitions assume the patient's head to be positioned with the Frankfort plane horizontal and the teeth in centric occlusion. The following definitions are based on the FDI standards which are accepted internationally.

INCISOR OVERJET

Overjet is the horizontal distance between the upper and lower central incisors measured parallel to the occlusal plane. It is measured from the labioincisal edge of one upper central incisor to the labial surface of the corresponding lower central incisor with the upper and lower teeth in centric occlusion. Where there is a difference between the left and right sides, the larger value is accepted. Where the upper and lower incisors bite in an edge-to-edge relation the overjet measurement is zero. When the lower incisors bite in front of the upper incisors overjet is measured as a negative value (Fig. 1). The measurement of overjet may be complicated by positional anomalies of the upper or lower central incisors such as rotation or crowding which make it difficult to choose points for measurement. The best one can do in these circumstances is to judge the most representative measurement of overjet in the individual.

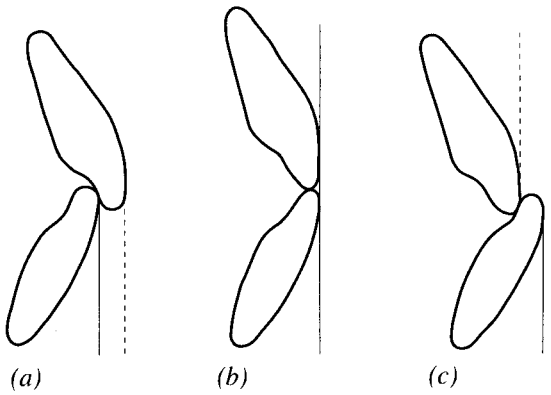


Fig. 1: (a) positive overjet (b) edge-to-edge overjet (c) negative or reverse overjet.

Overjet will often reflect the underlying skeletal jaw relationship but may also be dramatically modified by tipping of the upper or lower incisors. With a near normal

skeletal base relationship it could be expected that the overjet would fall within normal limits of 2-4 mm. This might be altered by a thumb sucking habit which causes proclination of the upper incisors and/or retroclination of the lower incisors with a consequent increase in overjet. Therefore, overjet is not always a reliable measure of the antero-posterior jaw relationship. The incisor reangulation method of skeletal assessment compensates for abnormal incisor angulations so that the adjusted overjet more truly reflects the underlying skeletal pattern. Adjust the angulations of the upper and lower incisors to normal values by rotating around the axis of rotation at about the junction of the middle and apical thirds of the root.

INCISOR OVERBITE

Overbite is the vertical distance between the incisal edge of the upper central incisor and the incisal edge of the lower central incisor. Ideally the upper incisors will cover approximately one third of the crown height of the lower incisors – about 3-4mm. It is often more meaningful to refer to the degree of overbite as the percentage overlap of the lower incisor crown height by the upper incisor – for example, one third coverage is referred to as 30% overbite. Where there is a difference between the left and right sides the larger value is recorded.

There are a number of local factors which determine the magnitude of the overbite.

1. Crown lengths of the incisors
2. Shape and size of the upper incisor cingulum
3. The angle at which the upper and lower incisors meet – interincisal angle
4. Soft tissue patterns or digit sucking habits
5. Anterior face height.

On occasions the soft tissue interference from the tongue or the lips, or both, may actually prevent contact between the upper and lower incisors. Lack of contact between the upper and lower incisors is classified as either incomplete overbite or openbite. Incomplete overbite implies that the upper and lower incisors overlap in the vertical plane but do not contact. Openbite implies that the teeth do not overlap at all in the vertical plane (Fig. 2). Openbite may be measured as negative overbite, e.g. – 3mm overbite. Occasionally openbite is measured as a separate trait. As with overjet, we may also have an edge-to-edge overbite which implies zero overlap in the vertical plane.

Overbite is one of the determinants of mandibular function because it governs the amount of separation of the upper and lower teeth as the mandible is protruded with the teeth in contact. Disclusion of the posterior teeth eliminates cuspal interferences as the mandible protrudes. Overbite may also be an indicator of vertical skeletal relationships. As the facial pattern becomes longer and the mandibular plane angle becomes steeper, the incisors are unable to maintain positive overlap. Conversely the overbite may be increased in people with a short square facial pattern. However,

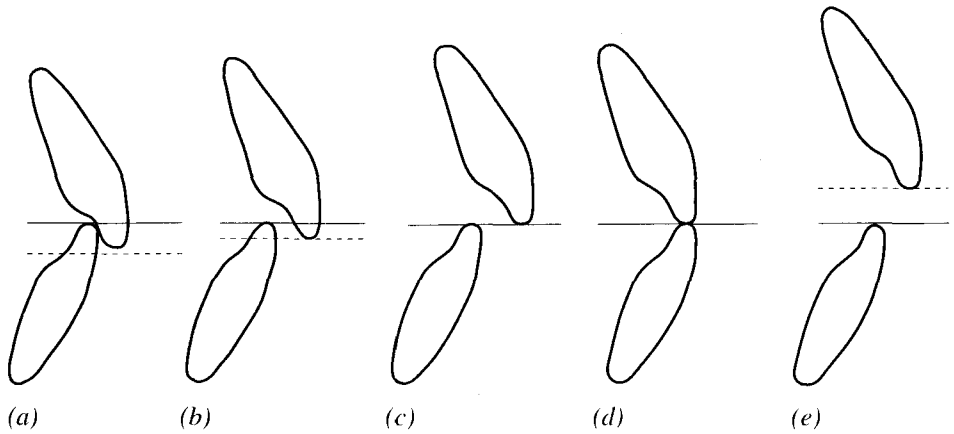


Fig. 2: (a) complete overbite (b) incomplete overbite (c) edge-to-edge overbite (d) edge-to-edge overbite (e) openbite.

as with overjet the overbite is subject to variation due to other factors such as digit sucking or tongue thrusting.

BUCCAL OVERJET AND OVERBITE

By convention, the unqualified terms overjet and overbite refer to the incisors. However, it should be remembered that overjet and overbite may also be measured on the buccal teeth (Fig. 3). Buccal overjet will be discussed further under buccal crossbite. Buccal overbite, like incisal overbite, is an important determinant of mandibular function in lateral excursions. Overbite in the canine region, in particular, is a very important occlusal guide and from it is derived the term canine rise.

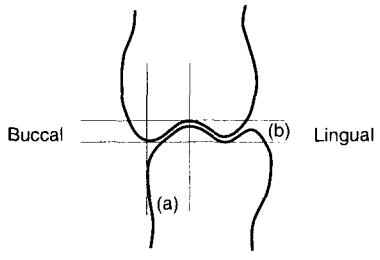


Fig. 3: (a) buccal overjet measured horizontally from the cusp tip of the upper tooth to the cusp tip of the lower tooth (b) buccal overbite measured vertically from the cusp tip of the upper tooth to the cusp tip of the lower tooth.

CROSSBITE

The term crossbite is used to describe the facio-lingual relationships of the upper and lower teeth. Anterior crossbite has already been discussed indirectly under the definition of negative or reverse overjet. However, it is possible to have a positive overjet measurement and an anterior crossbite in the same mouth – one lateral incisor

for example. Crossbite occurs when the upper tooth lies behind the edge-to-edge position in lingual relation to an opposing lower tooth (Fig. 4).

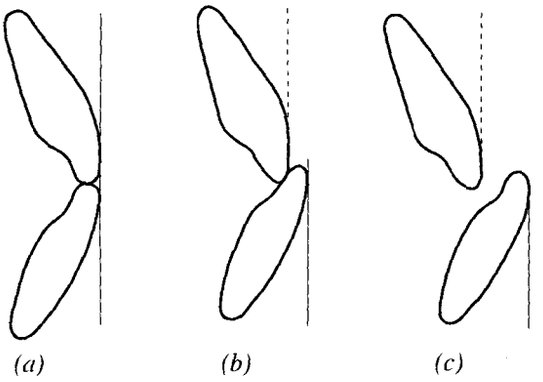


Fig. 4: (a) edge-to-edge bite (b) anterior crossbite with contact (c) anterior crossbite without contact.

Similarly, posterior crossbite occurs when the upper posterior tooth lies beyond the edge-to-edge position in relation to an opposing lower tooth. Commonly the term posterior crossbite refers to a lingual posterior crossbite (Fig. 5). But a posterior crossbite may also result from relative buccal displacement of the upper tooth beyond the edge-to-edge position to a buccal posterior crossbite or a scissor bite (Fig. 6).

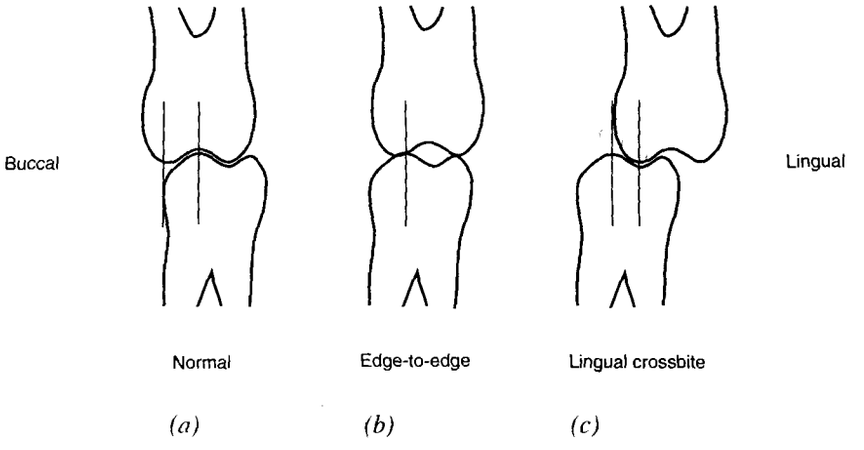


Fig. 5: (a) normal buccal overjet (b) edge-to-edge bite (c) lingual crossbite

Crossbites are important for several reasons. In the anterior section of an arch they may be associated with marked malalignment of one or more teeth and therefore cause poor appearance. Often there is abnormal wear of the labial surface of the incisor in crossbite. Dental interference due to anterior or posterior crossbite may result in a mandibular shunt from the retruded contact position to the intercuspal position. Avoidance displacements of the mandible may occur in the anterior and lateral directions. Both anterior and posterior crossbites may be indicative of cuspal

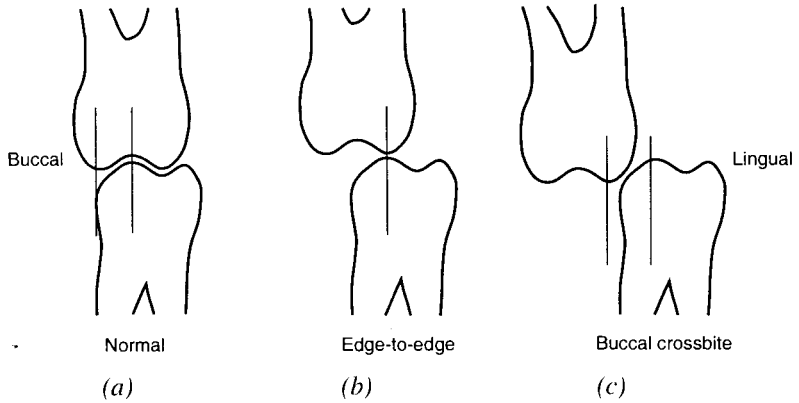


Fig. 6: (a) normal buccal overjet (b) edge-to-edge bite (c) buccal (scissor) crossbite.

interference on closure of the teeth causing displacement of the mandible to an abnormal intercuspal position.

Posterior crossbites may be associated with lingual contraction of the upper arch causing space shortage. Where a crossbite is not causing a functional or esthetic problem, there may be grounds for accepting the anomaly particularly in older patients who have never displayed any symptoms of dysfunction (Fig. 7).

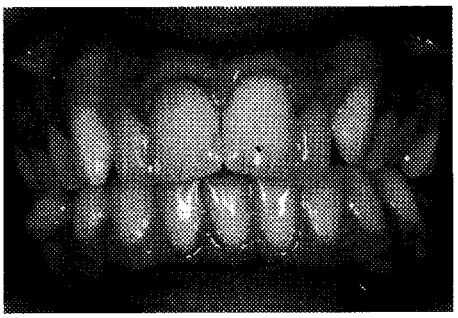


Fig. 7: Posterior crossbite of long standing associated with upper arch contraction. The patient declined treatment and suffered no symptoms of temporo-mandibular dysfunction.

CENTRE LINE DISPLACEMENT

With the teeth in centric occlusion (intercuspal position), the absolute positions of the upper and lower centre lines are assessed by using the midline of the face as a reference. The relative positions of the centre lines are assessed by measuring displacement of the lower centre line (to left or right) relative to the upper centre line. Displacements of centre lines may occur in various combinations. Large displacements may be quite disfiguring. Displacement of the lower relative to the upper centre line will disturb the arch relationships of the upper and lower teeth in both the anterior and buccal segments (Fig. 8).

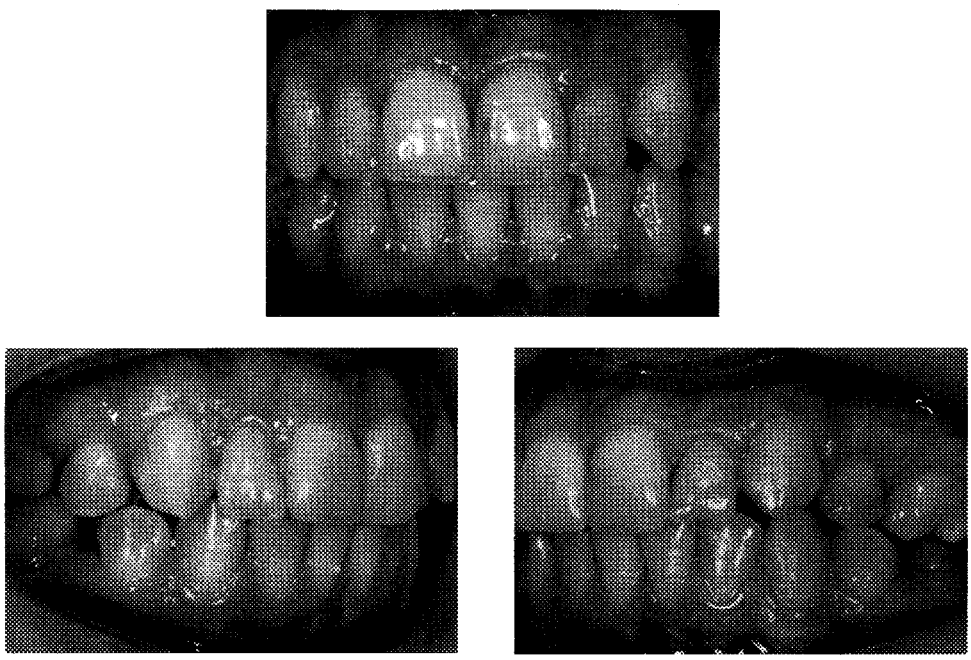


Fig. 8: Displacement of upper centre line to the right side associated with a Class I canine relationship on the right side and a Class II canine relationship on the left side.

BUCCAL SEGMENT RELATION

The teeth in the upper buccal segments normally occupy a specific antero-posterior relationship to the teeth in the corresponding lower buccal segments. A stylised representation of the buccal segments on one side of the dentition shows the following relationships in a normal dentition (Fig. 9).

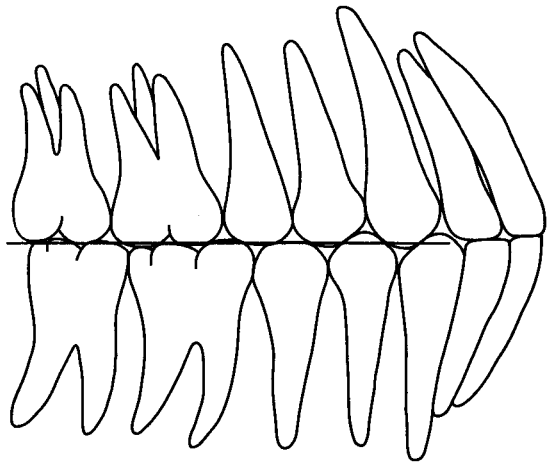


Fig. 9: Normal buccal segment interdigitations and occlusal plane (line of occlusion) bisecting the overbite in the buccal segments.

1. The tip of the upper canine lies in the embrasure between the lower canine and lower first bicuspid.

2. The tip of each upper bicuspid lies in the embrasure between the corresponding lower bicuspid and the tooth behind it.

3. The mesiobuccal cusp of the upper first molar lies in the buccal groove of the corresponding lower first molar and the distobuccal cusp of the upper first molar lies in the embrasure between the lower first and second molars.

Departures from ideal in either direction, mesially or distally, are not necessarily classified as abnormal. Even when the displacement from ideal is moderate it does not necessarily warrant treatment.

CENTRIC OCCLUSION

(Intercuspal Position — ICP)

Centric occlusion is the occlusal contact relationship of the upper and lower teeth when the teeth occlude in the position of maximum habitual intercuspation. In simple terms, it is the position of maximum occlusal contact or meshing of the teeth which is habitually adopted by the patient when the teeth are brought together. Maxillo-mandibular dental relationships such as overbite and overjet are conventionally measured with the teeth in centric occlusion.

CENTRIC RELATION

(Retruded Contact Position — RCP)

Centric relation is the relationship of the mandible to the maxilla when each condyle lies in the most retruded unstrained position in the condylar fossa at a given vertical dimension. Centric relation, therefore does not depend on the presence of teeth. In the final stages of closure in the dentate individual from rest position, the condyles rotate and the teeth contact in the retruded contact position (RCP). Certainly there should be no discrepancy between the RCP and ICP in a lateral direction although there may be slight tolerable differences up to 1 mm in the anter-posterior direction which may still be termed normal. One of the most important causes of a displacement from RCP to ICP is occlusal interference due to crossbite – either anterior or posterior.

OCCLUSAL PLANE

The occlusal plane in orthodontics is measured on the cephalogram and is variously defined by different authors. It has been defined as the line joining the tip of the mesiobuccal cusp of the upper first molar and the incisal edges of the upper central

incisors. It has also been defined as the line joining the point of bisection of the overbite at the central incisors and at the first permanent molars. Finally, it has been defined as the plane bisecting the overbite of the teeth in the buccal segments from the first permanent molars to the canines - this is referred to as the line of occlusion or functional occlusal plane (Fig. 9). The last definition has been proposed to eliminate variations in the position of the occlusal plane which result from abnormal vertical incisal relationships and is the preferred definition used in orthodontics. For example the upper central incisors in a Class II division 2 malocclusion may be grossly overupted such that an occlusal plane drawn to these teeth gives no indication of their vertical position relative to the buccal line of occlusion. Occasionally however where buccal teeth are unerupted the clinician may be forced to use the first molars and incisors. But comparisons between pre-treatment and post-treatment occlusal plane angulations would not be very useful in analysing the effects of treatment.

ARCH DEPTH

Arch depth is the perpendicular distance from labial aspect of the labio-incisal edges of the central incisors to a line drawn between the mesial contacts of both first permanent molars or the distal contacts of both second deciduous molars (Fig. 10). The measurement of arch depth will reflect the stages of dental development and the biggest change will occur after loss of the deciduous second molars with forward migration of the first permanent molars. Where deciduous teeth and particularly second molars have been lost early, the measurement of arch depth will be changed by local circumstances. Where the deciduous early loss occurs on one side only, the landmarks become disturbed and may render the measurement useless.

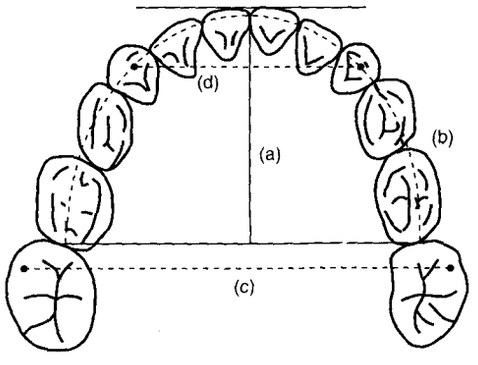


Fig. 10: (a) arch depth (b) arch circumference (c) intermolar arch width (d) intercanine arch width.

ARCH CIRCUMFERENCE

Arch circumference is the distance measured round the arch from the mesial contact of one first permanent molar to the mesial contact of the other first permanent molar. In a normal arch it is measured through the contact points and estimates the space available in the arch (Fig. 10). When teeth are displaced from their normal

positions the arch circumference is measured as a smooth curve through the estimated correct arch shape ignoring the displaced teeth. Arch circumference may be measured in several ways. Moorrees (1959) recommended the measured wire technic where a piece of brass wire was formed into a curve to reflect the arch line and the length anterior to the first permanent molars measured. Alternatively an occlusal photocopy of the cast allows the arch circumference to be drawn more accurately and measured in smaller segments.

ARCH WIDTH

Arch width is the distance measured between homologous teeth on opposite sides of the arch. It is most commonly measured between the tips of the buccal cusps of bicuspids and molars or the tips of the canines. Canine arch width is a very important arch dimension which should not be expanded during orthodontic treatment. For the purposes of longitudinal research in children during the development of the dentition, equivalent points are chosen on the deciduous teeth and their permanent successors. This is likely to lead to some inaccuracies because the crowns of the deciduous and permanent teeth have different morphologies – but that is the best that can be done.

SIX KEYS TO NORMAL OCCLUSION

An occlusion does not have to be perfect to be normal. Small departures from ideal do not mean that an occlusion is abnormal. Indeed a slight amount of crowding in the lower incisor region is so common as to be classified as normal. It is difficult to define simply what constitutes a normal occlusion. Andrews (1972) described the keys to normal occlusion. The source of these ideas was the examination of one hundred and twenty dentitions that had never been treated orthodontically and were judged not to need treatment. From Andrews work we interpret the following concepts:

1. Molar Relationships

The mesiobuccal cusp of the upper first permanent molar falls within or occludes in the buccal groove between the mesial and middle cusps of the lower first permanent molar.

The distal surface of the distobuccal cusp of the upper first permanent molar occludes with the mesial surface of the mesiobuccal cusp of the lower second permanent molar. This requires a distal tilt of the upper molar long axis relative to the lower molar (Fig. 11).

The mesiolingual cusp of the upper first molar seats in the central fossa of the lower first molar.

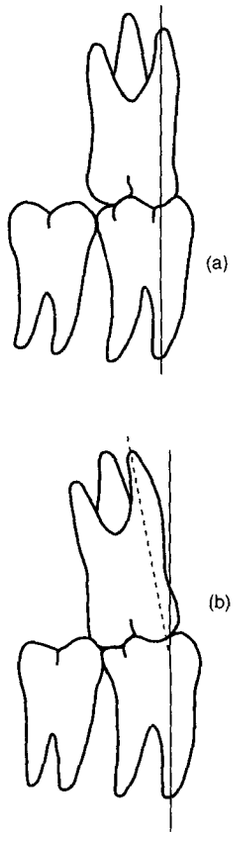


Fig. 11 (a) near normal first molar relationship with upper first molar too upright (b) true normal molar relationship with distal tilt of upper first molar.

2. Mesiodistal Crown Divergence

A direct view of the labial or buccal surface of each tooth, shows the mid-gingival portion of the crown to be more distally placed than the mid-incisal edge or cusp tip. This reflects the slight mesiodistal angulation of each tooth. The amount of distal crown divergence varies slightly for each tooth type but is seen in all cases with a pleasing normal occlusion (Fig. 12). The upper central incisor for example shows a distal crown divergence of about 5 degrees. If teeth become more vertical in the mesiodistal dimension the crowns occupy less space than they should to maintain correct contact point relationships.

3. Labiolingual and Buccolingual Crown Inclination

(a) A line drawn tangent to the mid labial surface of the incisor crowns shows that the labial surfaces of the crowns of the upper and lower incisors are inclined slightly labially and reflect the correct labiolingual inclinations of the long axes of the incisors themselves. The correct labial inclinations of the incisor crowns is an important determinant of the overbite and inter-incisor contact relationships. As the incisors

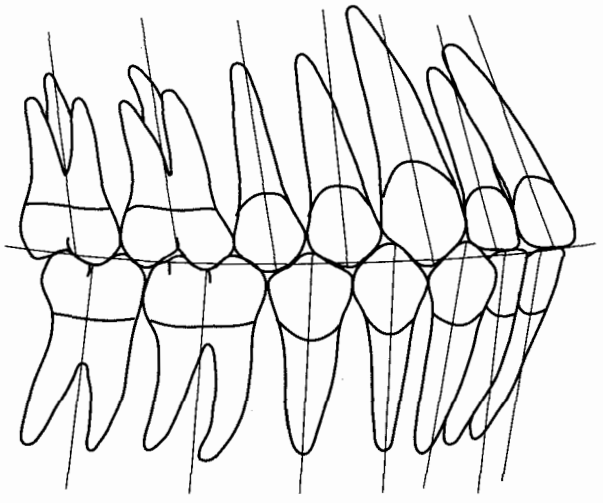


Fig. 12: Mesio-distal crown angulations with a slight forward slope of each line drawn through the long axis of each crown.

become more upright or even lingually inclined, the contact relationships of both the incisors and posterior teeth deviate further from normal (Fig. 13).

(b) The buccal surfaces of the crowns of the canines, bicuspids and molars are inclined slightly lingually toward the occlusal surface. In the upper arch the lingual inclination is only slightly more pronounced in the molars than in the bicuspids and canines. In the lower arch lingual inclination of the buccal surfaces increases progressively from the canine to the second molar (Fig. 14).

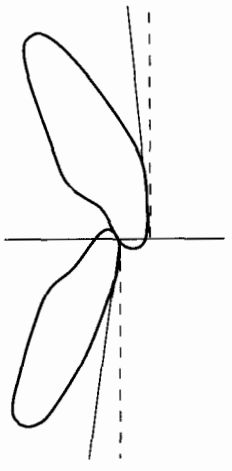


Fig. 13: Normal inclinations of incisor crowns.

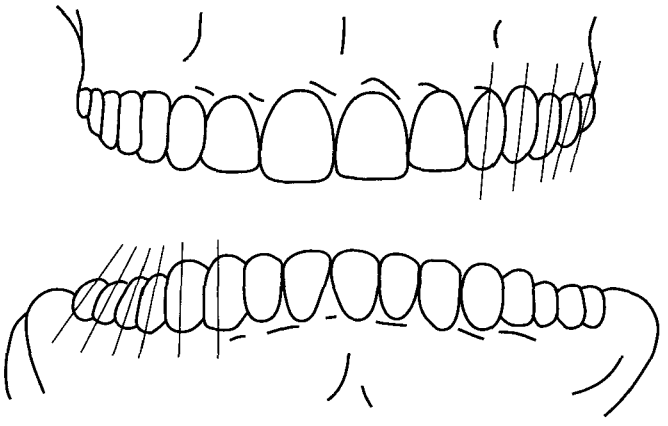


Fig. 14: Normal inclinations of the buccal surfaces of teeth in the posterior segments. In the upper arch the inclination increases slightly in the molar region. In the lower arch the inclination increases progressively from canine to second molar.

4. Rotations

All teeth should be free of rotations. A rotated incisor may occupy less space than normal, while a rotated molar or bicuspid occupies more space than normal.

5. Contact Points

In the large majority of normal occlusions the teeth are in proximal contact. This implies that the upper and lower teeth must be matched in mesiodistal widths. The Bolton analysis provides a readily referenced series of corresponding upper and lower tooth sizes which are matched and therefore fit together in normal occlusion. Bolton's analysis may also be used to compare the widths of upper and lower teeth where a discrepancy is suspected due, for example, to small upper lateral incisors.

6. Curve of Spee

The curve of Spee is the natural progressive upward curvature of the teeth proceeding from the incisors through the bicuspids to the molars. It should be nearly flat and should not exceed approximately 1.5mm in depth (Fig. 12). A deep curve results in a confinement of the upper arch creating spillage of the upper teeth mesially and distally. A relatively flat curve is best suited to a normal occlusion.

FUNCTIONAL OCCLUSION

The six concepts discussed are static. But do they meet the demands of a good functional occlusion? These static criteria allow teeth to function in a mutually protective occlusion without cuspal interference and without joint dysfunction. They allow a harmony of retruded contact position and intercuspal position. However, a failure to satisfy any one of the concepts does not automatically constitute a malocclusion nor does it mean that the patient is necessarily more likely to develop temporo-mandibular dysfunction. Most functionally and esthetically acceptable occlusions might be regarded as normal.

ARCH FORM AND OFFSETS

If we view the upper and lower arches from the occlusal aspect, and bend wires to the buccal surfaces of the teeth in those arches, we should see offsets in the position of the facial surfaces. These offsets are a function of the tooth morphology and are essential to the correct facio-lingual relationships of the upper and lower teeth in occlusion. In the lower arch the curve of the four lower incisors is smooth. The arch form then steps buccally around the prominence of the canine. The next step buccally is around the first and second molars. The upper arch offsets are the same as those in the lower arch except for the upper lateral incisor insets. These insets reflect the smaller labiolingual thickness of the upper laterals compared with the central incisors (Fig. 15).

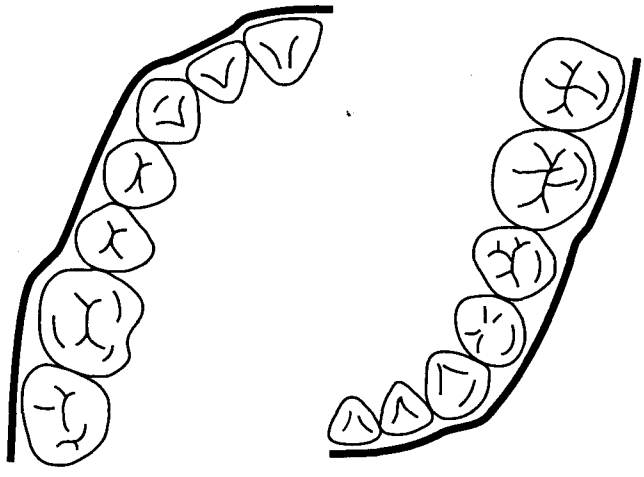


Fig. 15: Upper and lower arch offsets reflecting the relative positions of the facial surfaces of the incisors, canines and molars.

Modern fixed appliances are designed so that facial offsets and differential crown torque values are incorporated in the individual bracket bases and theoretically the clinician does not need to put these adjustments into the arch wire. However, where the problem calls for over-correction, auxiliary bends must still be individually designed into the arch wire – over-rotation, over-tipping or over-torquing.

CURVE OF MONSON (WILSON)

In normal occlusion the buccal cusps of the upper molars lie at a slightly higher level than the lingual cusps giving rise to a shallow curve. The cusps of the second upper bicuspids are flat, while the buccal cusps of the upper first bicuspids are slightly lower than the lingual cusps forming a shallow upwardly convex curve (Fig. 16). If the buccal teeth are inclined excessively lingually or buccally these curvatures may be upset leading to cuspal interferences. Where the teeth are buccally tipped before expansion or where the expansion is excessive, the lingual cusps of the upper teeth will become excessively elongated causing occlusal interference in border movements. The expanded position is also less likely to remain stable. Rapid maxillary expansion or surgically augmented expansion may be required in more severe cases.

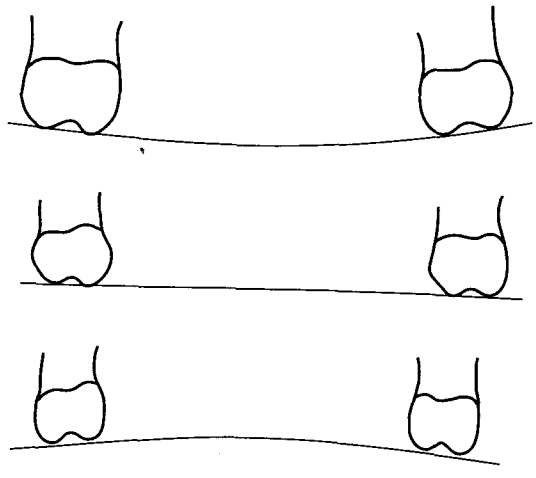


Fig. 16: Curve of Monson (Wilson) is negative at the first bicuspids, flat at the second bicuspids and positive at the first molars.

BOLTON ANALYSIS

The Bolton (1962) analysis is one method for analysing the relative combined mesiodistal widths of upper and lower teeth. Correct occlusion of the teeth as outlined in the keys to occlusion assumes that the upper and lower teeth are matched sets, as are the upper and lower artificial teeth chosen in setting up full dentures. With full dentures the teeth are chosen from matched moulds before trying to correctly articulate the upper and lower teeth. The Bolton analysis is an analysis of tooth widths which highlights disparities between the sum of the tooth widths in the upper arch compared to the sum of the tooth widths in the lower arch. It is worth pointing out that the Bolton analysis has no direct relation to the mixed dentition analysis.

SUM 321|123	SUM 321|123	SUM 321|123	SUM 321|123
40.0mm	30.9mm	48.0mm	37.1mm
40.5mm	31.3mm	48.5mm	37.4mm
41.0mm	31.7mm	49.0mm	37.8mm
41.5mm	32.0mm	49.5mm	38.2mm
42.0mm	32.4mm	50.0mm	38.6mm
42.5mm	32.8mm	50.5mm	39.0mm
43.0mm	33.2mm	51.0mm	39.4mm
43.5mm	33.6mm	51.5mm	39.8mm
44.0mm	34.0mm	52.0mm	40.1mm
44.5mm	34.4mm	52.5mm	40.5mm
45.0mm	34.7mm	53.0mm	40.9mm
45.5mm	35.1mm	53.5mm	41.3mm
46.0mm	35.5mm	54.0mm	41.7mm
46.5mm	35.9mm	54.5mm	42.1mm
47.0mm	36.3mm	55.0mm	42.5mm
47.5mm	36.7mm		

The Bolton analysis may be applied to the whole arch, upper and lower, or it may be applied to the anterior sections of the arches only. Most commonly only the anterior Bolton analysis is performed. The table of matched tooth widths (anterior only) is shown. It should be emphasised that clinical application of the Bolton analysis assumes that the teeth in both arches are at normal angulation to the respective Frankfort and mandibular planes. Note in particular, that as anterior teeth become more retroclined, they require less arch circumference at the incisal edge (cartwheel effect). This is why occasionally one sees cusp-to-cusp Class II buccal relationships and yet there is no crowding of the anterior teeth in the upper arch. The lingual inclination of the teeth places the incisal edges on a reduced circumference relative to the bulkier contact point areas of the teeth. It is most important in the treatment of Class II cases to achieve sufficient lingual root torque of the upper incisors to obtain correct axial inclinations and to slot the buccal teeth into good cusp-fossa relationships.

The records of a patient with a marked Bolton discrepancy of the incisors due to very small upper lateral incisors are shown (Fig. 17). There was also some crowding of the lower incisors. In order to balance the upper and lower incisor widths, one lower central incisor was extracted and the upper lateral incisors built up with composite resin. This allowed good Class I buccal segment relation to be maintained. The case was treated with fixed appliances and a major aim of treatment was to ensure root parallelism of the lower incisors in order to achieve a good inter-dental gingival contour and to prevent the occurrence of a triangular space between the adjacent incisors at the cervical margin level.

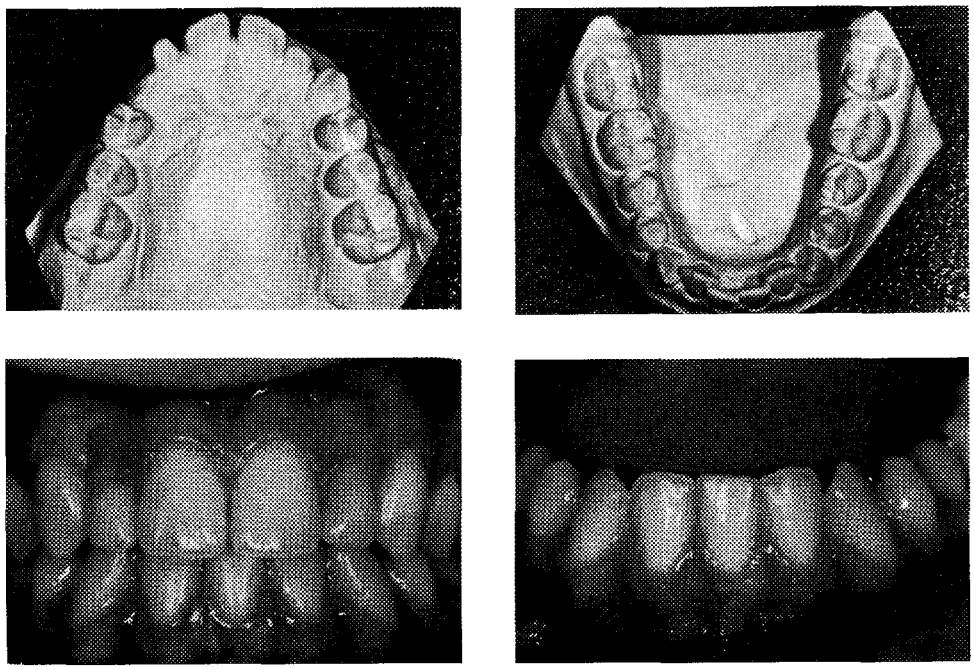


Fig. 17: Records of a patient with marked anterior Bolton discrepancy due to small upper lateral incisors. Treatment involved extraction of one lower central incisor and composite resin restoration of the upper lateral incisors.

SUMMARY

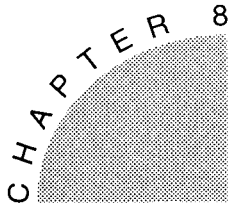
Deviations in tooth size, shape or arrangement according to the criteria discussed may lead to a departure from ideal occlusion and where that departure is mild, the occlusion may still be classified as normal. When that departure becomes excessive, leading to a deterioration in function or appearance, we may classify the occlusion as being a malocclusion.

References

Andrews LF (1972): The six keys to normal occlusion. Amer J Orthod 62:296-309.

Bolton WA (1962): The clinical application of a tooth-size analsis Amer J Orthod 48:504-29.

Moorrees CF: **The Dentition of the Growing Child.** Harvard University Press, Cambridge, Mass., 1959.



CLASSES AND CATEGORIES

CLASSIFICATION

Classifications in biological science may reflect a variety of traits. They may, for example, be based on shape, genealogy, etiology, function, composition, treatments or outcomes. A classification of malocclusion should at least provide an accurate, simple means of communication. It should be based on clear distinctions between classes so that they may be identified with a high degree of certainty and in terms of clinical utility should perhaps provide an indication of the type of treatment to be undertaken. To expect much more would be likely to lead to confusion. The terms classification of malocclusion and Angle's classification have become virtually synonymous in many orthodontic textbooks. This reflects the relative simplicity and acceptance of Angle's classification but also tends to disguise its shortcomings. Above all else, it is a method of coarse morphological categorisation. It gives a hint of the type of treatment required but its failure to address the lateral and vertical dimensions of malocclusion and dentofacial morphology precludes its application in the process of modern orthodontic analysis and treatment planning. Current practice suggests a need for re-evaluation of the utility of Angle's classification although pragmatism would further suggest that it is so universally ingrained in the orthodontic literature and nomenclature that it should be retained with qualification.

Angle's classification of malocclusion was proposed at the beginning of the twentieth century – almost 100 years ago. The original groups proposed by Angle were modified slightly in 1907 but the same basic group identities were maintained. Angle relied upon the upper first permanent molar as the key to his classification. Three classes were identified:

Class I – normal mesiodistal relations of the first permanent molars and indicating normal mesiodistal relations of the jaws (Fig. 1).

Class II – distal relation of the lower arch to the upper arch with the lower first permanent molars lying distally beyond the cusp-to-cusp position.

division 1 – protruded upper incisors (Fig. 2)
division 2 – retruded upper incisors (Fig. 3)

Class III – mesial relation of the lower arch to the upper arch with the lower first permanent molars lying mesially beyond the cusp-to-cusp position (Fig. 4).

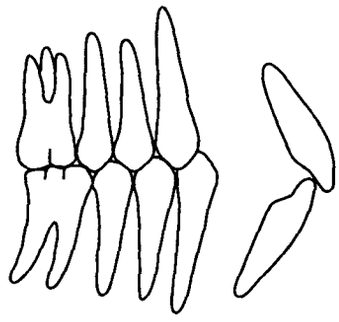


Fig. 1: Angle's Class I occlusion with the mesio-buccal cusp of the upper first permanent molar occluding in the buccal groove of the lower first permanent molar.

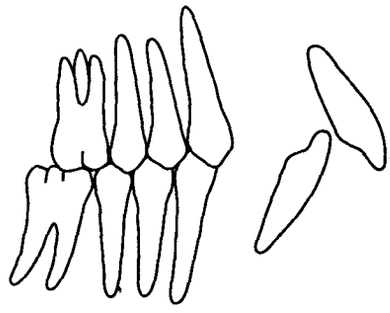


Fig. 2: Angle's Class II division I occlusion with the mesio-buccal cusp of the upper first permanent molar occluding in the embrasure between the lower first permanent molar and the second bicuspid. The upper incisors are protruded.

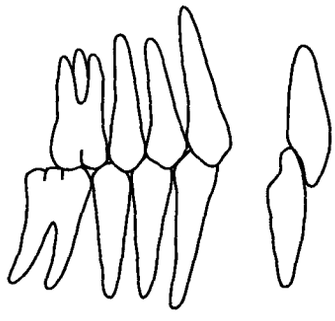


Fig. 3: Angle's Class II division 2 occlusion with the mesio-buccal cusp of the upper first permanent molar occluding in the embrasure between the lower first permanent molar and the second bicuspid. The upper incisors are retruded.

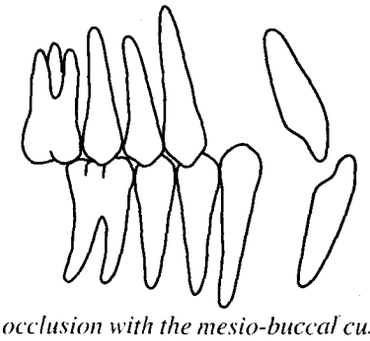


Fig. 4: Angle's Class III occlusion with the mesio-buccal cusp of the upper first permanent molar occlusing in the distal groove of the lower first permanent molar. The incisors are in crossbite.

Where one side only is displaced and the other is Class I, the malocclusion is referred to as a subdivision, e.g. Class II division 1, subdivision.

The dividing line between the classifications is set at the cusp-to-cusp position. Thus, any malocclusion up to and including the cusp-to-cusp position in either direction from Class I is still classified as Class I. Partial displacement is often described as a Class II tendency or a Class III tendency. It is interesting that Angle examined occlusal relationships in great detail. He noted that every tooth except lower central incisors and upper third molars should have two antagonists. He also noted that correct articulation between the upper and lower first molars requires a mesial crown angulation so that the distal marginal ridge of the upper first molar occludes with the mesial incline of the mesial cusp of the lower second molar – a point reiterated by Andrews (1972).

Difficulties arise where the first permanent molars have drifted due to local factors and distinctions between classes become blurred. Many clinicians have also found difficulty in confidently classifying all Class II malocclusions as either division 1 or division 2. The positions of the upper incisors are not always easily assessed as protruding or retruding. Thus while Angle's classification is seemingly simple it is often difficult to apply consistently.

The assumed constancy of position of the first permanent molars led to the further assumption that the teeth reflected the positions of the jaws. That assumption is now known to be false. Because of the difficulties caused by extraction or alteration of the position of the upper first permanent molar, it has been proposed that the canine be used to assess the true buccal segment relationship. Simon (1924) proposed the law of the canine which suffers from the same problem of possible alteration. However, the canine relationship offers a valuable backup in determining Angle's classification.

With the introduction of computers and their capacity to accurately sort and classify by means of a variety of algorithms, orthodontics is almost certainly moving into an era of more finely graded morphological classifications where Angle's classification will ultimately be of less practical use. However, for the moment Angle's classification persists as the didactic yardstick.

Angle's classification is a classification of dental arch relationships, not of skeletal relationships. While displacement of an underlying basal bone will obviously tend to carry the dental arch in the same direction, it does not follow that a given bony relationship will be always associated with a particular dental relationship. For example, it is possible to have a normal occlusal Class I relationship on a slightly Class II (retrognathic) bony base relationship. This may occur where all other factors associated with development of the occlusion are within normal limits and have overcome the skeletal discrepancy by directing the teeth to a normal occlusion by dento-alveolar compensation.

Confusion has arisen because the same terminology has been used for both dental and skeletal structures. Classes I, II and III refer to the same basic categories in

both the dental and skeletal systems. Further confusion arises because it is possible to have a Class II malocclusion on a Skeletal I base relationship and so on. Obviously, the more extreme the relative displacement of the underlying bony bases, the more likely it is that the associated dental classification will be the same because in these more severe circumstances other environmental factors, such as soft tissue influences, are unable to compensate sufficiently.

Classification is difficult where some teeth are absent, but the difficulty can usually be overcome by observation of adjacent teeth. Where the canines are erupted and aligned they may be of considerable help in deciding the true buccal segment relationship. Because Angle's classification does not necessarily give a good idea of the incisor relationships, added descriptors should be used to clarify the type of malocclusion. For example one might describe a case as an Angle's Class II division 1 malocclusion with proclined upper incisors and retroclined lower incisors. As cephalograms become more widely used, they provide the clinician with more detailed descriptors of tooth positions thereby supplementing the information available in the simple classification.

SKELETAL CLASSIFICATION

The classification of skeletal structures enables us to indicate whether or not there is a relative displacement of the upper and lower basal bones. Skeletal I indicates a normal antero-posterior skeletal relationship. Skeletal II indicates that the lower basal arch is relatively distal to the upper base and Skeletal III indicates a relative forward position of the lower basal arch. Common equivalent terms are normal, retrognathic and prognathic respectively. The basis of skeletal assessment may be either the SNA-SNB angular difference (Fig. 5), the incisor reangulation calculation or more recently the Wits analysis (Jacobson, 1975) has been widely used for the same purpose (Fig. 6).

The ANB angle is one basis for skeletal classification. The further the values of SNA and SNB depart from the norm, the less useful is the ANB difference as an indicator of the skeletal classification. The normal values of SNA and SNB are 82 degrees and 80 degrees respectively and the normal value of ANB is 2 degrees. Where the ANB difference is greater than 4 degrees this is termed Skeletal II. Where the ANB difference is 0 degrees or less this is termed Skeletal III.

The incisor-reangulation method of skeletal classification (Fig. 7) is more directly applicable clinically. In this method, the upper and lower incisor long axes are reangulated to normal relationships to Frankfort (109 degrees) and mandibular (90 degrees) planes respectively. If the Frankfort-mandibular plane angle is above or below the average value, an equivalent decrease or increase (inverse) adjustment is made to the expected value of the lower incisor to mandibular plane angle. For example, if the FMA was 30 degrees instead of 25 degrees the expected or normal value for the lower incisors would be 90 degrees minus 5 degrees = 85 degrees. The overjet remaining after reangulation, termed the residual overjet, is the basis of

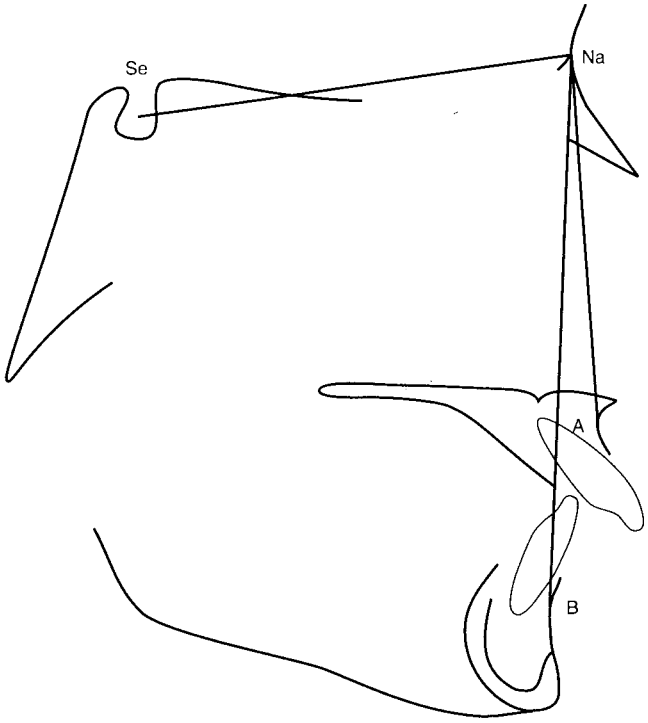


Fig. 5: SNA-SNB difference (ANB) as a measure of the skeletal classification.

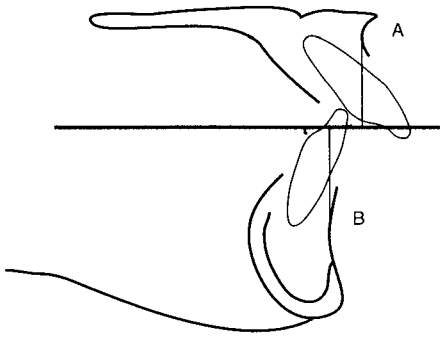


Fig. 6: Wits measurement is the distance between the projections of A and B points onto the occlusal plane recorded as a positive or negative value – in this case + 5 mm indicating a Class II skeletal base.

classification. A residual overjet of 2-4mm is normal or Skeletal I. A residual overjet greater than 4mm is Skeletal II while a residual overjet less than 2mm is Skeletal III. This system has the great advantage that it is a direct indicator of the extent and type of incisor movement required in orthodontic treatment.

If the residual overjet after reangulation is greater than 4mm, this indicates that some type of upper incisor torque is required to reduce the overjet and to maintain the correct incisor angulations and interincisal relationship. Alternatively, we might

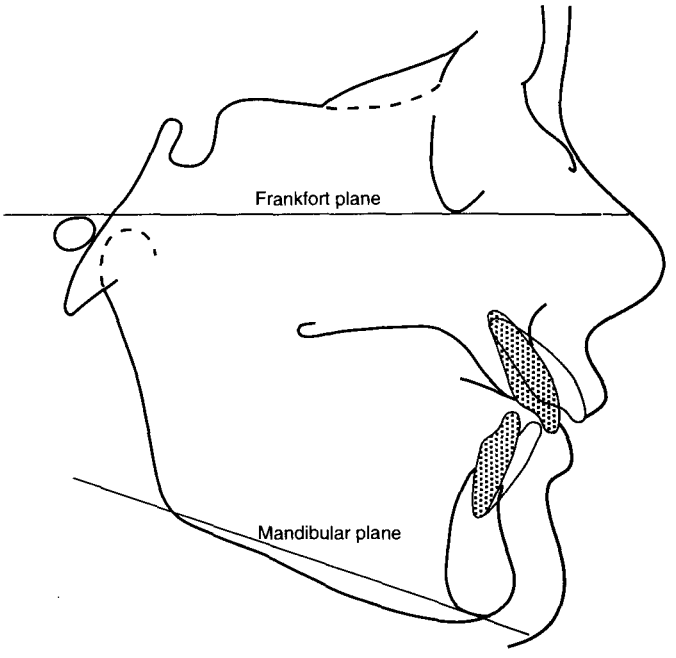


Fig. 7: Incisor reangulation method of assessing the skeletal pattern. Adjust the angulations of the upper and lower incisiors to normal values (shaded) and measure the residual overjet. In this instance the residual overjet is greater than 4 mm.

consider proclination of the lower incisor. However, this is rarely indicated as the preferred method of overjet reduction. The incisor reangulation method is a very useful adjunct to clinical treatment planning.

The Wits analysis compares the relative positions of A and B points projected onto the occlusal plane. A negative value is scored when B lies in front of A. The normal value is –1.0 mm for adult males and 0.0 mm for adult females. The analysis offers a simple and clear visualisation of the discrepancy between A and B points which reflects the skeletal pattern. As the Wits value becomes large (either positively or negatively) so the amount of tooth movement required to camouflage the skeletal discrepancy becomes more complex and requires more incisor root torque. In more extreme cases, orthodontic correction becomes impractical or even impossible. In these instances orthognathic surgical reduction of the skeletal discrepancy is often the method of choice.

CATEGORY DIFFERENCES

A variety of cephalometric measurements may be chosen to compare the morphology of cases within Angle's classes of malocclusion such as the angulations of the upper and lower incisors (MXIFH, LIMP), Frankfort-mandibular plane angle (MPA), Wits value and lower lip to E line (LLEL). This list is limited but demonstrates the point that the differences between Angle's types are sometimes more illusory than real. The following statistics are derived from separately assessed samples of Angle's classes.

	Classes and Categories			
	I	II(1)	II(2)	III
MXIFH	114.8 (8.0)	119.5 (8.5)	98.6 (9.4)	115.6 (6.5)
LIMP	92.0 (7.1)	95.4 (7.3)	90.3 (5.7)	86.7 (10.6)
MPA	25.6 (4.5)	24.8 (5.8)	22.7 (5.5)	28.1 (5.4)
Wits (mm)	0.5 (3.1)	3.3 (2.9)	3.5 (2.9)	-6.7 (5.7)
LLEL (mm)	- 1.9 (3.4)	-0.7 (3.7)	-3.1 (3.0)	-2.3 (3.7)

(mean and standard deviation)

The mean and standard deviation of each variable shows the typical group overlap that one sees for virtually all cephalometric variables. In the above examples the Class II division 2 group shows a significant difference for the upper incisor angulation. These group overlaps demonstrate the diversity of variation seen clinically and explain why Angle's classification with its limited categories is not able to provide detailed clinical guidelines to correct treatment even within the same class.

BUCCAL SEGMENT RELATIONS

The clinician is interested in buccal segment relationships for several reasons:

1. Orthodontic treatment planning is governed by these relationships, particularly extraction routines.

2. In the permanent dentition, without treatment, dental relationships are very stable and do not change as a rule.

3. To finish with an ideal occlusion after treatment, the molars must finish in a Class I relation. However, we don't always treat to Class I.

4. The concepts derived from Andrews' keys of occlusion provide sound objectives for orthodontic treatment and the better those objectives are achieved the better will be the finished result.

The ideal dental arrangement requires that twelve upper teeth (excluding second and third molars) occlude correctly with twelve lower teeth, when the teeth in both arches in good alignment (Fig. 8). This means that there must be no crowding and that the molar relationship must be Class I and the centre lines must be coincident. When the molar relationship departs from Class I, towards Class II or Class III, the inter-relation of the upper and lower arches becomes "less normal".

Crowding is a very common feature in the lower incisor region. The effect of this is to decrease the lower arch circumference. If the molars are still in Class I there must be a consequential effect on the upper arch – either crowding in the upper incisor region or an increase in overjet or a little of both. Twelve upper teeth in good alignment require twelve lower teeth in good alignment. If the lower arch circumference decreases, then the upper arch circumference must decrease or the overjet must increase if the molars are in Class I.

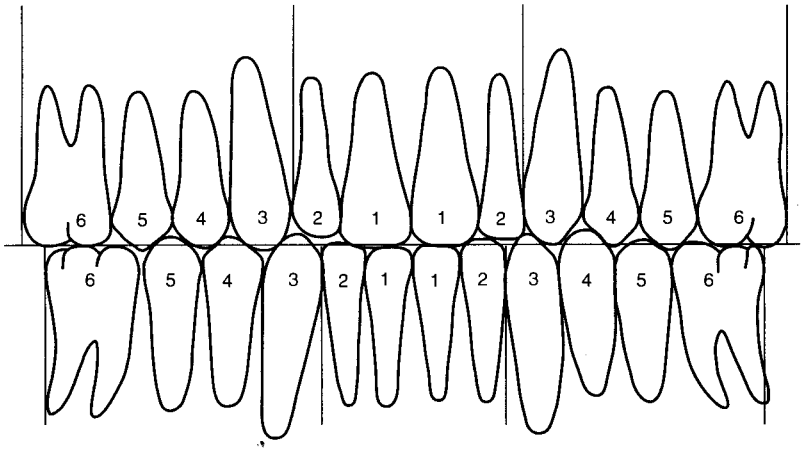


Fig. 8: A plan view of the normal anterior and buccal segment relationships.

In treating a Class II division 1 malocclusion to reduce the overjet the canine relationship must be corrected with the upper canine being moved back to lie in the embrasure between the lower first bicuspid and canine. If the upper first bicuspid is extracted and the canine moved back to Class I relationship, we are now fitting ten upper teeth to twelve lower teeth but leaving the first molars in a Class II relationship (Fig. 9). This is a perfectly acceptable arrangement providing there is no crowding in the lower arch.

In the case of a Class II arrangement with severe crowding in the lower anterior region, extractions in the lower arch will often be required to alleviate crowding. Normally extractions in the upper arch also would be required to reduce the overjet. The requirement now is to fit ten upper teeth to ten lower teeth (Fig. 10). If normal occlusion is to be achieved the buccal segments must be moved from a Class II to a Class I relationship. As a general rule this cannot be done with removable appliances. Therefore, a Class II case with crowding requiring extractions in the lower arch and with the molars in Class II, almost automatically becomes a fixed appliance case.

There is another practical difficulty with Class II cases with mild crowding in the lower incisor region. If it is decided to treat with removable appliances leaving the molars in Class II and extracting in the upper arch only, then the crowding in the lower arch often becomes much worse during or after treatment. This is due to the relative contraction of upper arch dimensions caused by the extractions. The contracting upper arch causes contraction of the already crowded lower arch.

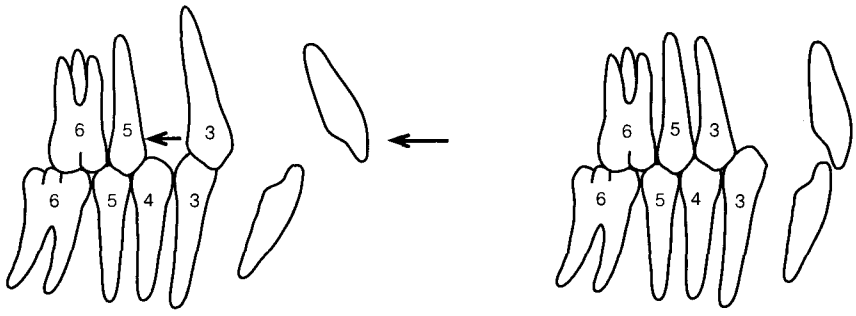


Fig. 9: Camouflage treatment of the Class II division 1 occlusion with extraction of the upper first bicuspid followed by retraction of the canine to a Class I relationship then reduction of the overjet. The molar relationship is left in a Class II position.

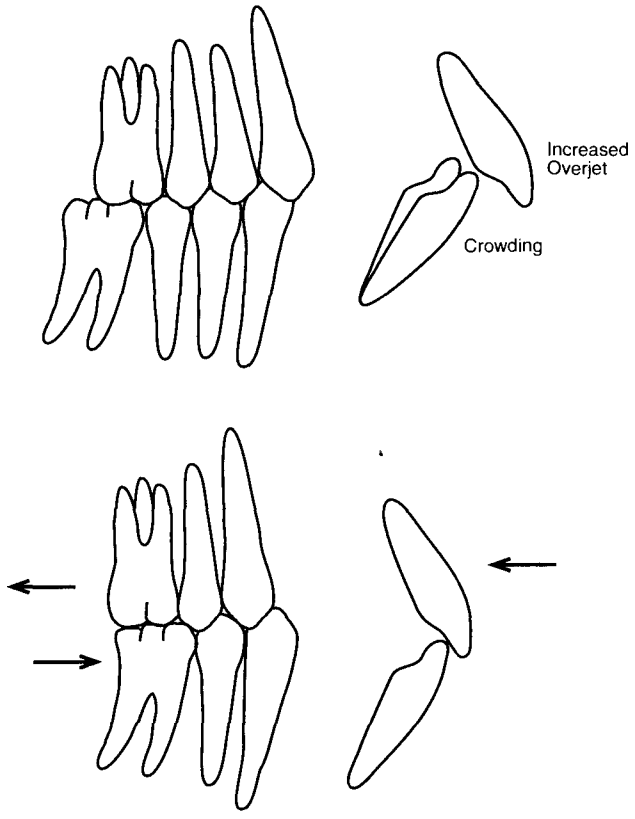


Fig. 10: A Class II division 1 malocclusion treated with extractions in both upper and lower arches. The treatment plan will also require correction of the molar relationship to Class I if a final normal occlusion is to be achieved.

The point has been made that in the permanent dentition, buccal segment relationships are very stable. However, in the mixed dentition where lower second deciduous molars are lost very early, a change may occur in relationships of the first permanent molars. For example, one might see a Class II malocclusion with

the first permanent molars in a Class I relationship because the lower first permanent molars have moved forward from a full Class II to a Class I relationship (Fig. 11).

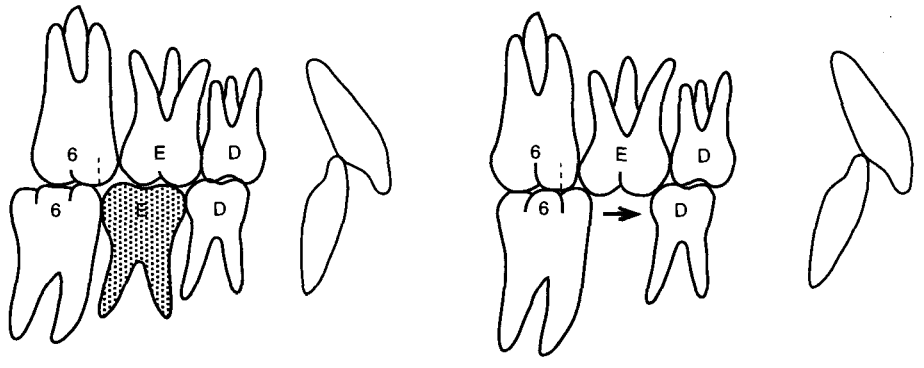


Fig. 11: Early loss of the deciduous lower second molar will allow forward drift of the first permanent molar into Class I relationship, usually with crowding in the second bicuspid region.

VERTICAL COMPONENT

Angle's classification pays no attention to the vertical components of the skeletal relationship. Vertical morphology is usually assessed in fairly simple terms by measurement of the Frankfort-mandibular plane angle (MPA) and the proportions of the upper and lower facial components. The normal value for MPA is about 28 degrees. A value greater than 35 degrees would indicate an excess vertical dimension (dolichofacial) while a value of 20 degrees or less would indicate a short lower face (brachyfacial). Other measurements such as the facial height angle of Ricketts would supplement the MPA.

Vertical skeletal patterns are not readily altered by orthodontic treatment alone although the type of vertical pattern may play an important part in determining the general thrust of the treatment plan. Treatment is usually aimed at not exacerbating the underlying vertical pattern rather than significantly changing it. In broad terms, extractions are discouraged in brachyfacial types because they lead to increased difficulty in controlling overbite and there is a stronger than normal horizontal growth pattern of the mandible with anterior growth rotation. Conversely, extractions tend to be more easily managed in dolichofacial cases where the amount of crowding warrants extractions. Where the vertical morphology is obviously so grossly abnormal as to be untreatable orthodontically, the most sensible option will usually be a combination of orthodontics and orthognathic surgery.

Ricketts has emphasised the need to consider the skeletal pattern for each patient in an integrated fashion with due consideration of all dimensions simultaneously. His facio-mandibular index is used to classify each patient as mesofacial, brachyfacial or dolichofacial. The FM index is the ratio of the antegonial width of the mandible to the nasion-menton height as measured on a frontal cephalogram with a value of

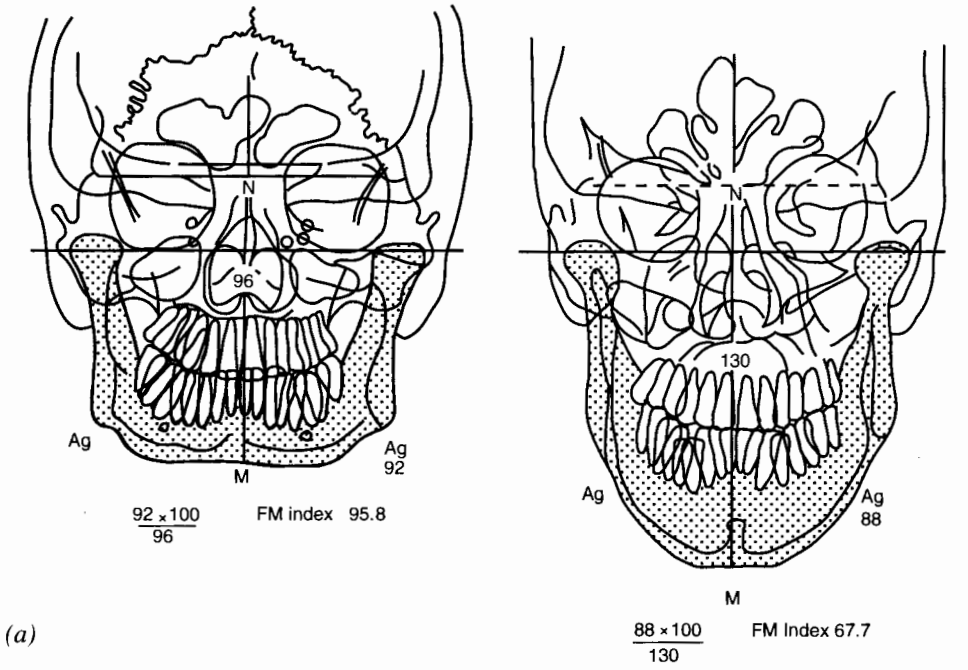
75% being normal. Brachyfacial types have a high index value indicating a relatively broad facial type with reduced facial height. Dolichofacial types have a low index value indicating a relatively narrower antegonial width and greater facial height. Note also that these classifications translate from the frontal view to the more commonly used lateral cephalometric view (Fig. 12).

MEDIO-LATERAL COMPONENT

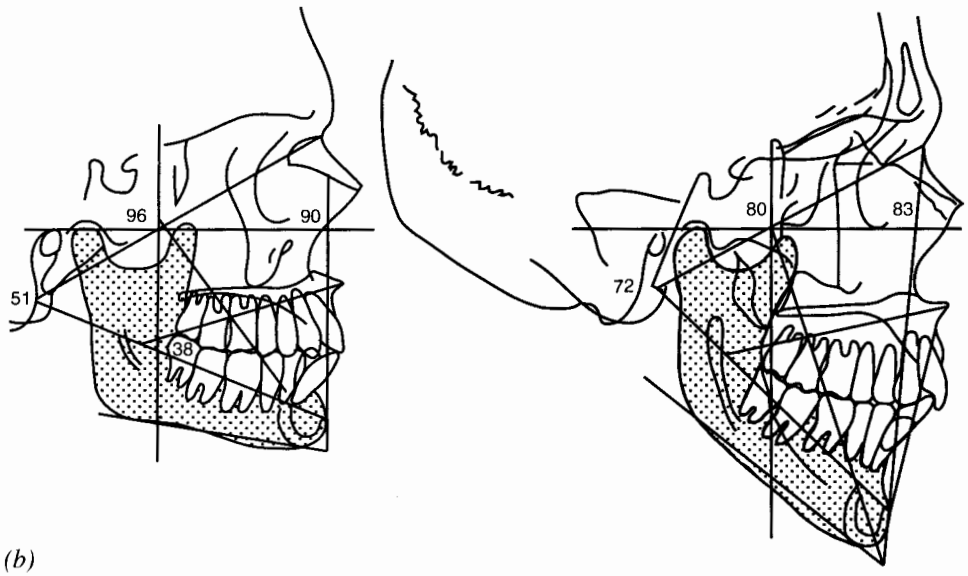
Neither does Angle's classification consider medio-lateral dental or skeletal relationships. Usually the only description in this dimension is to note the presence of a lingual or buccal crossbite. Once again the frontal cephalogram shows the relationships between the upper and lower facial structures and the accompanying dental arches. One of the most important aspects of dental relationships in this dimension is the angulation of the teeth. The long axes of the upper buccal teeth slope slightly to the buccal while the lower buccal teeth slope to the lingual. The axial positions of the teeth combined with their individual crown morphologies provide the correct relationships of the crowns to each other and the teeth to the underlying bone.

Discrepancies of dental relationships in the medio-lateral dimension may therefore only be compensated marginally by tipping the teeth. In the case of a lingual upper crossbite, the upper arch is usually expanded to conform to the lower although slight lingual lower tooth movement may be called for if the angulations allow correct interdigitation and therefore provide stability. Where the discrepancy becomes too great, correction may require rapid maxillary expansion with or without surgical augmentation in order to minimise tooth tipping and maximise movement of the bone segments.

Similarly, upper buccal crossbite (scissor bite) will usually be treated by combined buccal tipping of the lower teeth and lingual tipping of the upper teeth within the bounds of acceptable interdental angular relationships. Note also that many buccal crossbite problems are due to anteroposterior arch discrepancies, particularly in Class II malocclusions. The retrognathic jaw pattern 'carries' the narrower anterior arch dimensions more distally than normal so that the lower teeth lie inside the upper teeth. An equivalent effect may carry the lower teeth buccally in Class III malocclusions. Conversely, this crossbite coordination effect may come into play in the anteroposterior correction of jaw relationships during orthognathic surgery and orthodontic treatment prior to surgery must compensate for this expected effect.



(a)



(b)

Fig. 12: (a) The FM index of Ricketts calculated as the ratio of the antegonial width to the nasion-menton height (b) lateral view of some cases contrasting the brachyfacial type (left) with the dolichofacial type (right). (Redrawn from Ricketts RM (1989): ***Provocations and Perceptions in Cranio-Facial Orthopedics.*** RMO Inc page 240.)

INDEX OF OCCLUSION

An index of occlusion is yet another method of categorising malocclusion, a common objective being the determination of the severity of the condition. The index provides a composite score from the summation of index components to reflect the overall deviation from normal occlusion. The aim of some indices has been to provide an objective method for deciding who should receive treatment on a priority basis. Many indices of occlusion have been devised and one of the earliest and most widely used was the HLD Index (Handicapping Labiolingual Deviations) of Draker (1960). The concepts of most indices since then have changed little and they have been devised largely on the basis of clinical experience to determine which traits should be measured and accumulated. Cons, Jenny and Kohout (1986) published details of the DAI (Dental Aesthetic Index) after extensive statistical analysis of responses by patients, parents and dentists across various cultural environments. All indices result in significant rates of false positive and false negative assessment and this limits their utility in determining treatment need.

An index should possess the following attributes:

reliability – it should be reproducible by the same and different examiners
validity – it should actually measure what it purports to measure
flexibility – category boundaries should be variable to suit requirements

Validity is impossible to test robustly in orthodontics because there is no absolute standard, a point too easily obscured by a numerical index score. Therefore any decision to treat or not, based on an index score, is always open to challenge. The best that can be done is to test the performance of the index against the consensus views of patients and clinicians. Indices are useful as epidemiological tools but none of those presently available can be applied to the evaluation of need or outcomes of treatment without considerable qualification.

Components of the DAI:	**Weight**	**x Score**	**Component Value**
1. Missing visible teeth	6	3	18
2. Crowding	1	2	2
3. Spacing	1	0	0
4. Diastema	3	0	0
5. Largest anterior irregularity – upper	1	4	4
6. Largest anterior irregularity – lower	1	3	3
7. Anterior maxillary overjet – upper	2	6	12
8. Anterior mandibular overjet – lower	4	0	0
9. Vertical anterior openbite	4	0	0
10.Antero-posterior molar relation	3	2	6
		Index Value	45

(DAI value of 32.5 has been suggested as the cut off between treatment and no treatment).

Note that the weight indicates the relative importance of the particular component as determined by previous statistical analyses. For example, a measurement of maxillary overjet of 7 mm would be multiplied by a factor of 2 to give a score of 14 for that component. The scoring of a particular example is shown.

Indices and classifications of malocclusion serve different purposes but they are often closely related in that the index and the classification will almost certainly be based on some common components or traits. Dental education tends to stress the certainty of clinical decision making and the associated treatment planning processes. However, all clinical decision making is subject to variation due to personal interpretation of the clinical symptoms. The component values of an index infer a degree of numerical exactitude which is not warranted by their clinical performance. No index can be better than the data on which it is based.

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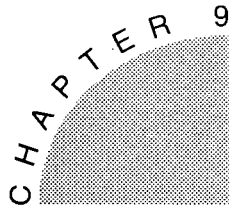
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EXTRACTIONS

SERIAL EXTRACTION

Serial extraction is the procedure of extracting deciduous teeth during the course of development of the occlusion in order to make space initially for erupting crowded permanent incisors (Kjellgren, 1948). This is followed by further phases of extraction to make space for permanent bicuspids and canines. The classical serial extraction procedure calls for extraction of the deciduous canines at about the time of complete eruption of the permanent lateral incisors. This temporary space gain allows natural alignment of the incisors.

About eighteen months later, depending on the dental developmental stage, the first deciduous molars are extracted if the permanent canines are erupting ahead of the first bicuspids in order to accelerate eruption of the first bicuspids. Finally, the first bicuspids are extracted to allow the erupting canines to move occlusally, palatally and distally into the line of the arch without causing secondary crowding of the incisors (Fig. 1). In some cases of extreme crowding, even after extraction of the deciduous first molar the erupting first bicuspid may become caught under the mesial aspect of the second deciduous molar. In these instances extraction of the second deciduous molar may be warranted if eruption of the second bicuspid is at hand.

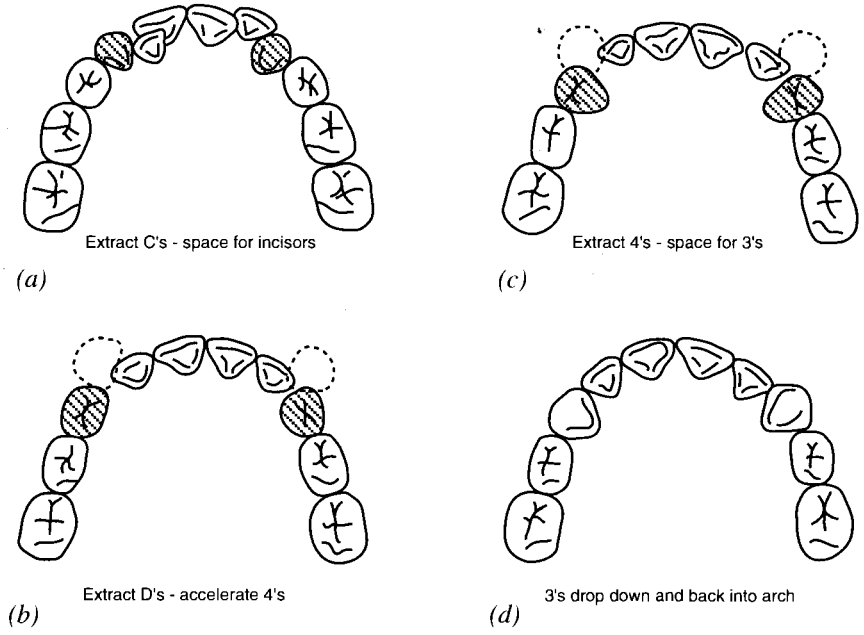


Fig. 1: Crowded upper arch (a) prior to extraction of C's (b) prior to extraction of D's (c) prior to extraction of 4's (d) final alignment of 3's after extraction of 4's.

Space maintenance may be required. Alternatively the mesial aspect of the second deciduous molar may be reduced to allow more room for the first bicuspid.

In some instances if the crowding is severe enough, prior exfoliation of the deciduous canine on one side only will occur with a resultant drift of the centre line to the same side. In this case the deciduous canine on the other side at least is extracted or where appropriate a serial extraction program is implemented (Fig. 2).

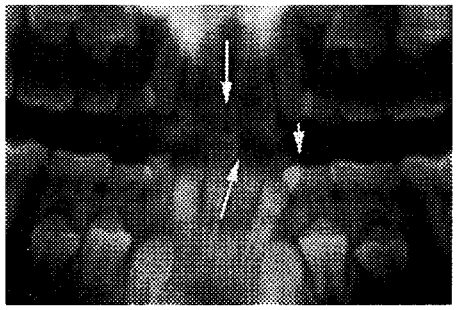


Fig. 2: Crowded arches with early exfoliation of lower left deciduous canine and shift of the lower centre line.

The original intent of serial extraction was to alleviate the incisor crowding and by extracting permanent teeth at the optimum time, to eliminate the need for further appliance treatment with natural closure of any residual space. Many difficulties arise in the application of serial extractions because they are often used when they are not indicated. They tend to cause lingual movement of the incisors with some increase in overbite. Orthodontists often extract deciduous canines and molars as an aid to permanent tooth alignment but do not follow up with permanent extractions. This may lead to some confusion by general practitioners in relation to the 'rules' of serial extraction. These latter extractions are not serial extractions. They are better termed 'extractions of convenience'. In other cases knowing that there will be an excess of space from extraction of permanent teeth, the orthodontist may embark on early extraction of teeth to encourage natural space closure in the knowledge that appliances will be placed later in order to complete treatment of the case to a high standard.

The requirements for the successful conduct of a serial extraction program are quite strict and if not fulfilled will lead to an unsatisfactory conclusion except with further appliance treatment. The following prerequisites reflect contemporary orthodontic thinking:

1. Crowding of sufficient degree to warrant the extraction of four permanent teeth, usually the first bicuspids. Crowding of more than approximately 8mm in the lower arch could be considered to warrant extractions in most Class I cases.

2. Patient's profile and skeletal pattern compatible with extraction treatment.

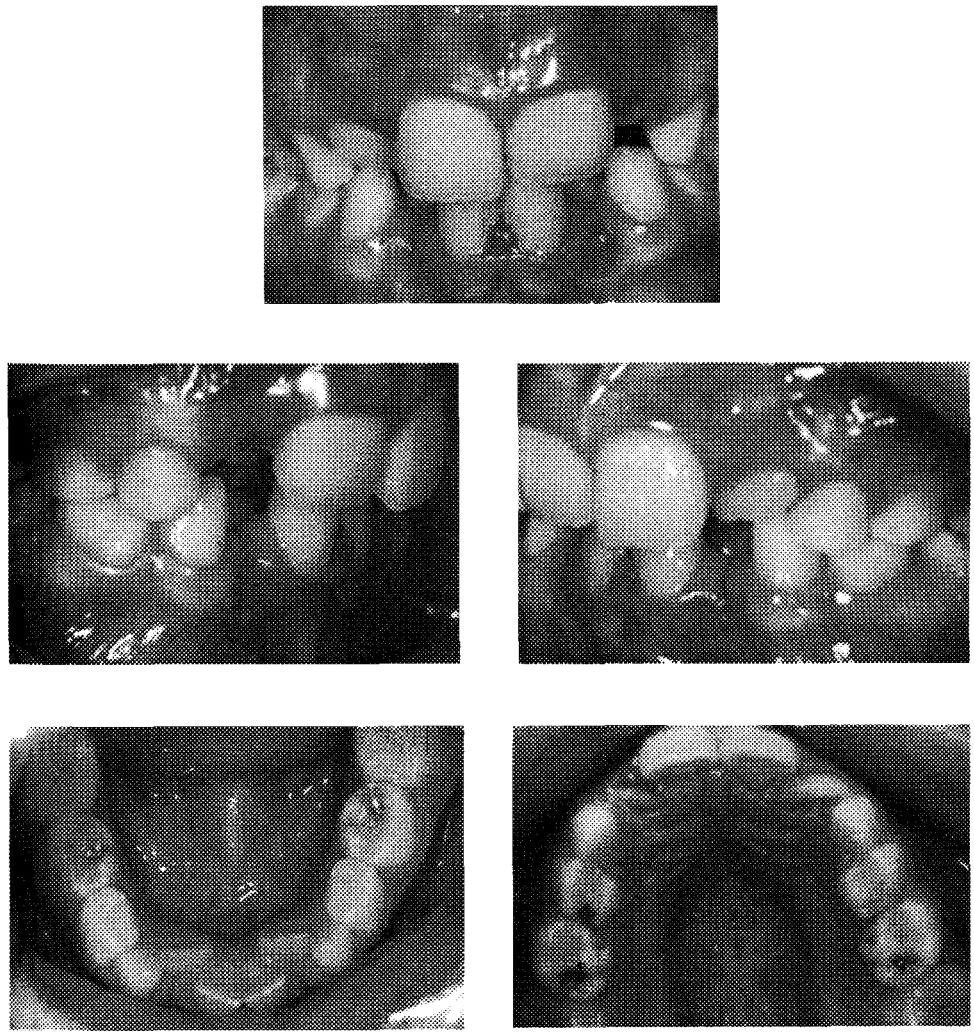


Fig. 3: Serial extraction case prior to extraction of deciduous canines.

3. Class I occlusion which does not require a change in buccal segment relationships.

4. No rotations of anterior teeth which require active de-rotation. In general, rotations will not improve much without treatment.

5. The mesiodistal angulation of the incisors should be acceptable and should not require active uprighting.

6. There should be complete eruption of the permanent lateral incisors to ensure that maximum arch width for that stage has been achieved.

7. Overbite should be within normal limits.

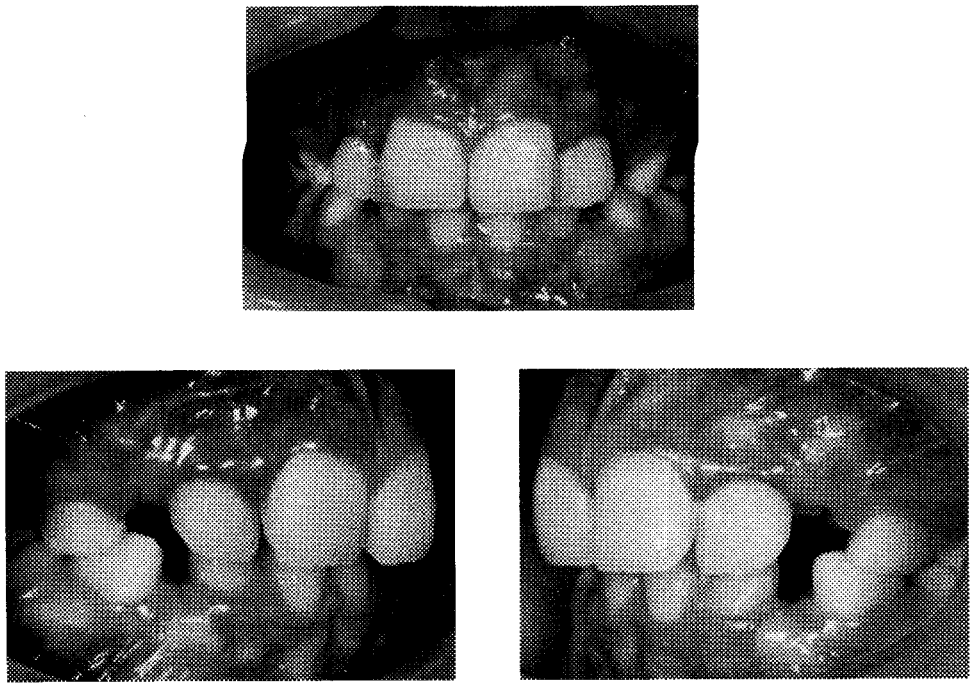


Fig. 4: Same serial extraction case after extraction of deciduous canines.

8. All permanent teeth should be in normal developmental positions so that natural drifting and correction of the teeth is not compromised. This applies particularly to the positions of the developing canines.

The number of cases where all these conditions are fulfilled is quite low. However, clinical situations are rarely clear-cut and the clinician may feel in some cases that substantial improvement will still occur and therefore extractions without follow-up treatment will provide a substantial net benefit to the occlusion. The aim of the 'rules' is to identify cases which can be treated satisfactorily by extractions alone (Figs. 3,4,5,6). Many cases will present with problems such as rotated teeth, which will clearly need further active orthodontic treatment. Serial extractions may still be of benefit in these cases, but the term 'extractions of convenience' is more accurate, because they are undertaken to achieve short term objectives in the expectation that appliance treatment will be required later. Very occasionally the alignment response after extractions may be unexpectedly good leading the clinician to be more adventurous with serial extractions. However, care should always be exercised.

PERMANENT EXTRACTIONS

The extraction of permanent teeth may be undertaken for a variety of reasons, not only the creation of space. It is often a difficult decision to make, requiring a balance

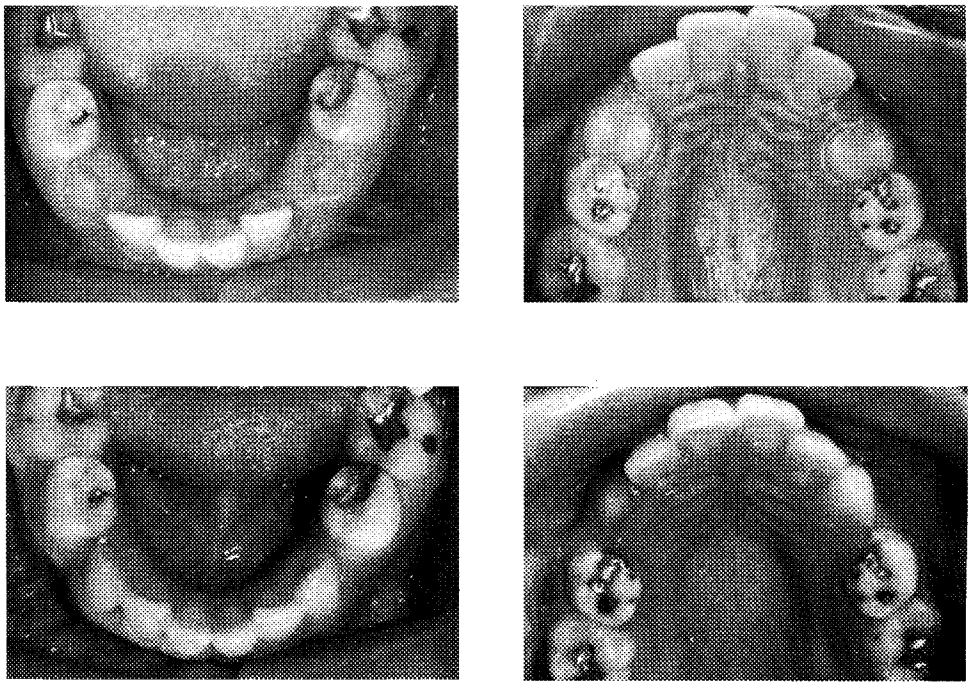
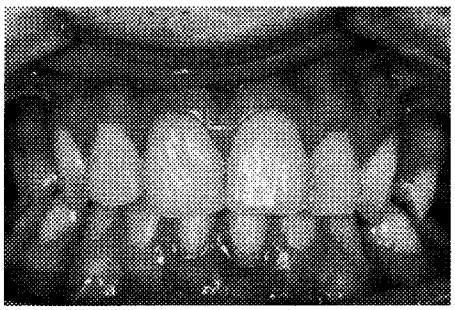


Fig. 5: Same serial extraction case prior to extraction of first bicuspids (top) and after extraction of first bicuspids.



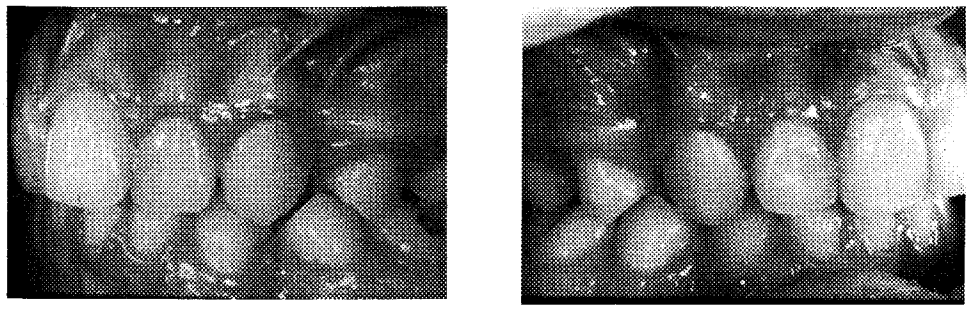


Fig. 6: Same serial extraction case after exfoliation of deciduous second molars and eruption of the permanent canines and second bicuspids.

between the amount of space needed and the amount of space created by extractions. Closure of space in excess of that required for tooth alignment may be a testing exercise in those cases where further retraction of the incisal segment toward the extraction spaces is not desirable. In such cases the clinician will strive to close the residual space by moving the buccal segments forward. However, assuming for example the extraction of first bicuspids, the imbalance in anchorage between six anterior teeth and six posterior teeth is obvious. Even if the second permanent molars are not banded, the second bicuspid and first molar offer considerably more anchorage than the canine and two incisors on each side and moving the posterior teeth forward requires the application of complex principles of biomechanics. In fact, excess space is often closed up by some retraction of the incisors.

Extraction of permanent teeth may be carried out for the following reasons:

1. To create space in order to relieve crowding.

2. To create space to reduce over-full soft tissues by retraction of the incisors and the overlying lips.

3. As an aid to anchorage, particularly in poor cooperators. For example, the operator might ideally prefer to treat a case with headgear but in the absence of cooperation, extractions may be the only practical alternative.

4. To allow treatment without the need to change buccal segment relationships. This commonly occurs in Class II division 1 malocclusions where the molars are left in a Class II relationship and extractions are performed in the upper arch only.

5. To enhance bite closure in openbite and dolichofacial cases. These types generally show a tendency to increased lower face height. Non-extraction treatment may exacerbate the situation, particularly headgear treatment which pushes the molars back into the inter-maxillary wedge.

6. To overcome anomalies where teeth are missing on one side, are particularly small as occurs occasionally with upper lateral incisors or there is a gross Bolton discrepancy requiring extraction in the opposing arch.

7. To decompensate the dentition prior to orthognathic surgery with extraction in the upper arch of Class III cases and in the lower arch of Class II cases.

8. Poor prognosis due to caries or periodontal factors.

The selection of teeth for extraction depends on several factors, not least of all on the preferences of the individual operator. Various combinations may be advantageous in some circumstances rather than taking the same tooth in each quadrant. Extraction of upper first bicuspids and lower second bicuspids may allow easier space closure and buccal segment correction in some Class II malocclusions.

Where a centre line is badly displaced, the extraction of a first bicuspid on one side and the second bicuspid on the other side may make centre line correction very much easier in selected cases.

FIRST BICUSPIDS

The most commonly extracted teeth are the upper and lower first bicuspids. These teeth are close to crowding in the incisor segments and allow alignment of the anteriors directly into the extraction spaces. Each bicuspid has a mesiodistal width of about 7.1mm. Thus extraction creates about 14.2mm in each arch. It is rare to find this much crowding in any arch and the excess must be used up in several ways

1. Forward movement of the remaining buccal teeth.
2. Retraction of the incisors.

Generally, true forward movement of the buccal segments is easier to achieve in the maxilla than in the mandible. Therefore, care should be exercised to ensure that extractions in the mandible do not result in over-retraction of the lower incisor segment with deterioration of the interincisal angle.

Occasionally upper bicuspids only are extracted when the Class II buccal segment relationship is to be accepted. Extractions in the upper arch only, create certain problems. Extractions effectively reduce or contract all arch dimensions including intermolar width, intercanine width and arch circumference and when confined to one arch there tends to be a mutual effect on the opposing arch with consequent crowding. Not infrequently extraction in one arch is associated with progressive crowding in the opposing arch. If the crowding increases too much extraction in the opposing arch must be considered as well. However, this has consequences in correcting the buccal segment relations in order to finish the case correctly. For these reasons it may be better to carefully assess the need for extractions in both arches at the start of treatment and to extract in both arches followed by fixed appliance therapy to close residual spaces and correct a Class II relation to Class I.

When upper first bicuspids are to be extracted prior to eruption of the canine, it may be advantageous to delay appliance treatment and allow the adjacent teeth to drift into better alignment while the canine erupts. Where space is only just sufficient it will be necessary to place a passive space maintainer such as a palatal arch or a removable appliance if cooperation is good.

SECOND BICUSPIDS

Second bicuspids are often extracted when the degree of crowding is minimal and it is hoped to close residual space from behind to minimise retraction of the incisor segment. Because only the permanent molars have to be moved forward there is less reciprocal effect on the anterior anchorage, with less retraction of the incisors.

Another fairly common occurrence is the congenital absence of lower second bicuspids often requiring extraction of the deciduous teeth and space closure. Extraction of the second deciduous molars is often neglected in these cases until after the first bicuspids erupt. It is only when the second deciduous molar begins to submerge badly that extractions are considered. With earlier extraction, natural space closure due to mesial shift of the posterior teeth may substantially reduce the space although appliance therapy is often required at some point.

In broad terms, extraction of lower second bicuspids does not give a satisfactory result unless managed with fixed appliances. When allowed to drift forward by itself, the lower first permanent molar often tips forward and rotates leaving a contracted alveolus between the molar and first bicuspid. One other disadvantage associated with lower second bicuspid extraction is the relative size and shape of the first bicuspid. The lower first bicuspid is most often smaller and of a different shape from the second bicuspid and its convex distal contact does not sit well against the first molar. Due to the narrow mesio-distal width of the first bicuspid, second bicuspid extraction may result in a space distal to the first bicuspid. Second bicuspid extraction is often a compromise treatment and not recommended without the availability of fixed appliances to close space effectively and ensure root parallelism of adjacent teeth.

Many of these comments also apply to the extraction of upper second bicuspids. While the shape difference is not as marked as in the lower arch, the upper first bicuspid has a flat distal contact which may not give an ideal contact with the first molar. In addition, excess space will lead to tipping and rotation of the molar which may warrant fixed appliance correction. Another extraction combination which is sometimes undertaken is upper first bicuspids and lower second bicuspids. This is usually performed in Class II division 1 cases where the space requirement is greater in the upper arch in order to reduce the overjet. It also aids correction of the Class II relationship.

SECOND PERMANENT MOLARS

The extraction of second permanent molars is a little used option. The usual aim of any extraction is to create space. Second molars are so far from the front of the arch that they effectively create less useable space than a bicuspid. The nature of crowding in the dental arch may vary considerably. In some cases it occurs mainly in the anterior region of the arch and extraction of the first bicuspid is the best solution. In other cases it occurs in the mid-arch region and extraction of a second bicuspid may be more desirable. In yet other cases the crowding may occur substantially in the posterior region of the arch as evidenced by crowding of the erupting third molars or by stacking of the upper third molars above the second molars (Fig. 7). These different types of crowding do not occur alone. They may occur in combination in the same case. However, where the crowding is mainly in the posterior regions, extraction of the second molar may offer the most practical solution providing the third molar will erupt satisfactorily.

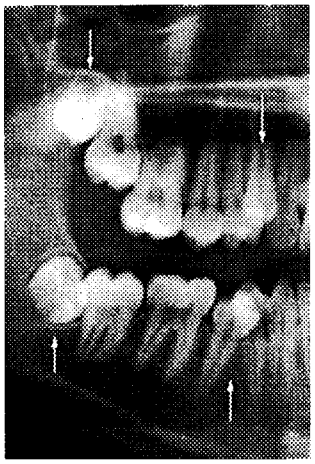


Fig. 7: Right side of an OPG x-ray in a patient aged 15 years. There is stacking of the upper second and third molars, potential impaction of the lower third molar and mid-arch crowding of the upper canine and lower second bicuspid.

The extraction of lower second molars to allow the eruption of lower third molars is a very complex diagnostic question and even under the best of circumstances cannot be guaranteed to result in satisfactory eruption of the lower third molar. In the upper arch, the third molar will nearly always erupt satisfactorily after extraction of the second molar. However, the size of the upper third molar is sometimes unacceptably small.

There are rare occasions where crowding and potential impaction of third molars suggest that second molar extraction is the best course. Some authors have also recommended second molar extraction to overcome poor headgear response in the upper arch. Unfortunately, poor headgear cooperation is never overcome by extractions so there may still be no improvement of the molar relationship. In a case where upper second molars may be marked for extraction along with headgear treatment, it is often better to have the patient demonstrate good cooperation and some tooth movement prior to any extractions.

Occasionally the combination of upper second molar and lower third molar extractions may be warranted. This has the disadvantage that the lower second molar may overerupt and disturb the migration and final occlusion of the upper third molar. One of the disadvantages of this combination is that it commits the clinician to a long period of observation until all teeth have erupted satisfactorily. This may take several years.

LOWER INCISOR EXTRACTION

There is probably no more inviting extraction procedure in the presence of medium to severe lower incisor crowding than extraction of one lower incisor. However, a

good many factors need to be considered before extracting a lower incisor. As a general rule, lower incisors ought not to be extracted in developing or young adult dentitions where further changes with growth or occlusal settling can be expected. Where there is obvious pathology associated with a lower incisor, the question becomes less pressing. Where there is no Bolton anterior tooth size discrepancy, the most immediate effect of extracting a lower incisor is to actually create such a Bolton discrepancy. In essence, the extraction of one lower incisor reduces the lower intercanine arch circumference compared to the upper intercanine arch circumference, thus making it difficult to achieve anterior occlusion with normal overbite and overjet. Not uncommonly, the reduced lower anterior arch circumference leads to a deepening of the overbite.

The other aspect of lower incisor extraction which must be stressed is the need to over-correct mesiodistal axial inclinations of the adjacent teeth. In addition, pericision may be indicated where teeth were badly displaced prior to treatment. Failure to over-correct incisor angulations adjacent to the extraction site results in some post-treatment relapse with adjacent teeth tipping toward each other creating a disfiguring triangular space between the crowns.

UPPER INCISORS

The extraction of upper incisors is rarely a preferred option and in most cases where it is undertaken there is an overriding pathology or morphology problem. Trauma may result in luxation, discolouration and severe root resorption thereby forcing the decision to extract the incisor in preference where extractions are required. Unfortunately the extraction or loss of an upper central incisor causes a major imbalance between upper and lower anterior tooth widths. While the lateral incisor may be crowned subsequently to simulate a central incisor the aesthetic result is often disappointing. The cervical width of the lateral incisor at the gingival margin requires that the crown taper excessively from the incisal edge and it nearly always looks out of place. The increasing availability of osseo-integrated implants will influence treatment planning in this region.

FIRST MOLAR EXTRACTIONS

The extraction of first permanent molars is usually done where the long-term prognosis of these particular teeth is poor. A mistake that is sometimes made is to extract first molars where no extractions are indicated. For example, where the mouth shows no signs of crowding, extraction of even questionable first molars is not indicated and may in fact create more problems than it solves. This is particularly so where there is no follow-up fixed appliance treatment to close spaces effectively. It is rare that all first permanent molars are of the same poor standard and a combination of various teeth may be preferable to extracting all four first molars.

The first molars are important keystones of the developing occlusion and in the absence of severe crowding, their extraction, without follow-up fixed appliance treatment, usually leads to deterioration of the occlusion. In addition, the uncontrolled drifting of molars is an important cause of balancing side interferences in mandibular excursions and may cause pain dysfunction syndrome in later life.

There are occasions where the condition of first molars demands their extraction in preference to other teeth. In these instances, some problems can be eliminated by correct timing of the extractions. In the lower arch the first molars should be extracted as early as possible to encourage as much forward movement as possible without tipping of the second molar. The relatively slow rate of forward drift of the second molar usually means that space management is not a problem except in the most severely crowded cases.

Extractions in the upper arch are either done at the same time as lower extractions or are delayed depending on the amount of crowding or the presence of a Class II buccal segment relation. Upper second molars drift forward relatively quickly and may finish up against the second bicuspid. For this reason, if the space created by extraction is required for either de-crowding or buccal segment correction to Class I, it is better to delay extraction of the upper first molar. It may be necessary to wait until the second molar has actually erupted so that it can be restrained from forward movement thus allowing maximum utilisation of the space. Where the upper and lower molars are extracted at different times it is necessary to watch that the erupting lower second molar is not unduly impeded by any over-eruption of the upper first molar. In such instances, it may be desirable to extract the upper first molar when the lower second molar has erupted. If necessary, an upper space maintainer can be placed to hold the second molar back.

CANINE EXTRACTIONS

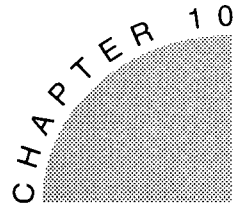
The extraction of a permanent canine may be carried out in preference to the first bicuspid where the canine is in a poor position. In fact it makes little sense to subject any patient to extraction of the bicuspid to be followed by heroic recovery procedures aimed at bringing the canine into place. Such treatments are protracted and may fail because of a loss of cooperation. The age at which many impacted canines are detected is in the teens or early adulthood when the patient is socially active and not happy to accept a very long treatment schedule. Common sense ought to prevail.

Aberrant canine eruption can usually be detected in the late mixed dentition by careful clinical examination involving location of the canine crown bulge in the buccal sulcus and examination of the long axis of the lateral incisor. Any suspicions should be checked on x-ray. Early detection of an abnormal position may warrant extraction of the first deciduous molar to encourage early eruption of the first bicuspid. This will often de-crowd the canine crown allowing it to drop back. If the deciduous canine is still present, this should also be extracted. Care must be taken

to ensure that space is not lost. If the second deciduous molar is still present it will often be enough to hold the first permanent molar back, particularly if it is occluding in a good Class I relationship. Centre line drift due to unilateral deciduous tooth loss should also be watched closely.

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TOOTH MOVEMENT

PERIODONTIUM

The teeth are attached to alveolar bone by means of periodontal fibres which pass from the cementum across the periodontal space to bone. Fibres also pass from the supracrestal cementum to the gingival tissues and to the cementum of adjoining teeth. The support system has three components – hard tissue (bone and cementum), soft tissue (mainly collagenous) and a fluid component. The fluid component is situated between two inflexible structures and acts as an important cushion. The interstitial fluids cannot be easily displaced from within this relatively closed complex.

The periodontal ligament of the young functioning tooth is about 0.25mm wide. It is a highly vascular structure with four main functions – supportive, nutritive, formative and sensory. The ligament contains both pain and proprioceptive receptor endings which play an important part in feedback control of the muscles responsible for the movements and spatial relationships of the mandible. The supportive fibres of the ligament are called the principal fibres, being arranged in four groups. The alveolar crest fibres extend from the alveolar bony crest to the adjacent cementum. The horizontal fibres lie just below the alveolar crest and pass horizontally from bone to cementum. The oblique fibres account for the major portion of the ligament and run from bone in an apical direction to the cementum. The apical fibres radiate from the apical portion to bone (Fig. 1a). The directions of the fibres give efficient support to lateral and vertical displacements of the tooth. The fibre bundles of non-functioning teeth show poor organisation and atrophic changes.

The concept of a central or intermediate plexus in the periodontal ligament suggests that the fibres are not continuous but are spliced together from the bone on one side and the tooth on the other. It is further proposed that this plexus is an active area of mitosis allowing for changes in position of the tooth with growth and movement. Other workers have questioned the existence of a plexus in humans. Areas of marked collagen synthesis suggest that the principle of a plexus is useful for practical purposes. The blood supply of the ligament is very rich and arises from the intra-alveolar, inter-dental and dental arteries. There is an elaborate anastomosis of vessels supplying the ligament, alveolar bone and pulp canal. The periodontal ligament is also the site of cementum formation and repair, an essential aspect of the connection of periodontal fibres to the tooth.

The gingivae are intimately connected with the periodontal ligament and the tooth (Fig. 1b). The free gingiva encircles the tooth and when healthy lies in close proximity

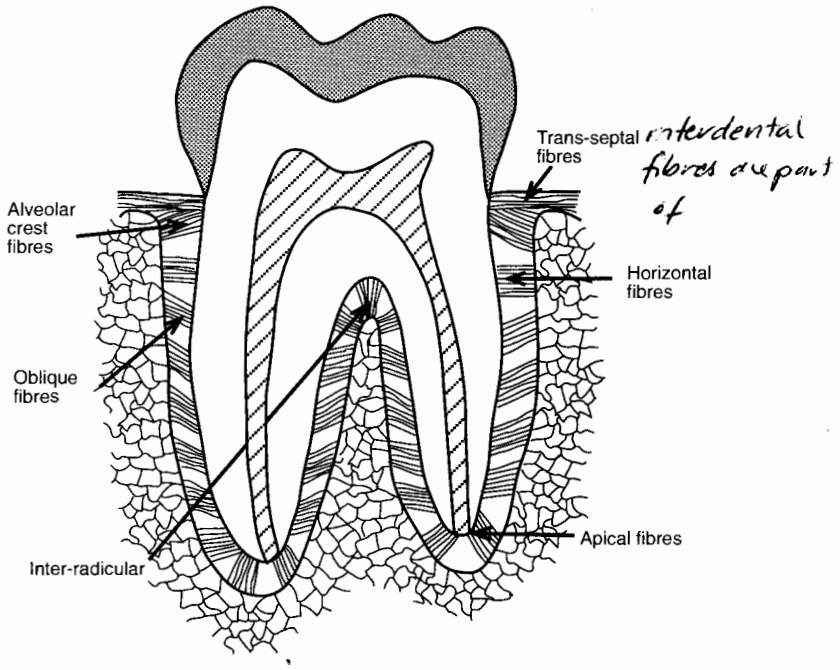


Fig. 1a: Periodontal ligament and main fibre groups.

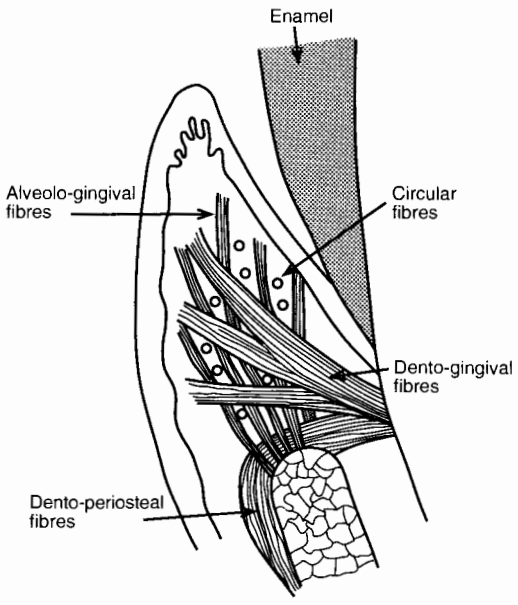


Fig. 1b: Fibre groups in the gingival region.

to the enamel. Fibres of the alveolar crest region are divided into four groups including the dento-gingival, alveolo-gingival, dento-periosteal and circular fibres. Besides attaching from cementum to the alveolar periosteum, some fibres of the dento-periosteal group connect to the cementum of adjacent teeth and are known as trans-septal fibres. They are capable of drawing a tooth in the same direction as an adjacent tooth which is being actively moved.

TOOTH MOVEMENT

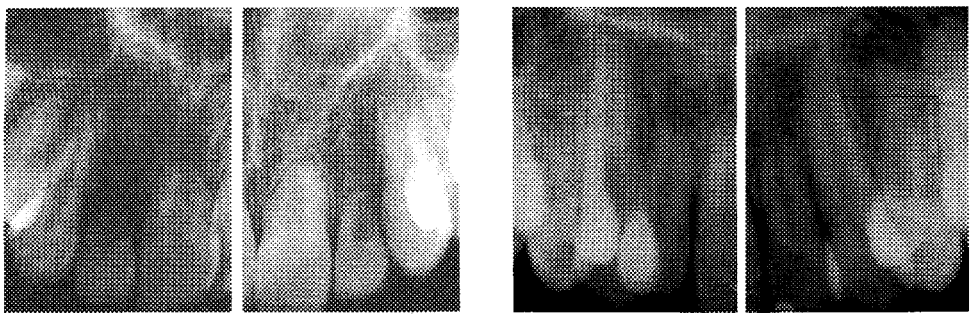
The application of a continuous or intermittent force to a tooth results in areas of pressure and tension in the periodontal ligament. Within two to three days osteoclasts migrate into the area of compression and resorption commences although actual tooth movement may take up to two weeks. Resorption does not occur simultaneously across the whole compression front but in circumscribed areas to be followed by a period of rest and reattachment of periodontal fibres. On the tension side of the same tooth osteoblasts respond with bone apposition. The force tends to push the tooth against the alveolar bone causing compression of the ligament. The tooth moves in two distinct stages. The first movement is small and due to tissue distortion and bone elasticity and will depend partially on the level of force. Subsequently, the osteoclastic and osteoblastic processes lead to bone resorption and apposition resulting in movement of the tooth through bone.

The relationship between blood supply and bone turnover is obvious but what level of force will achieve bone removal and apposition most efficiently without damage to either ligament or tooth? Schwarz (1932) suggested that the force applied should not exceed capillary blood pressure at about 25gm/cm^2. Storey and Smith (1973) suggested that a force of 200 gm/cm^2 is required to move canines bodily whereas Ricketts et al (1979) have advocated a force of about 80 grams. Excessive force may result in hyalinisation of the ligament, damage to cementum and tooth resorption. Application of the correct levels of force will result in frontal surface resorption of the lamina dura because the blood supply of the associated ligamental structures is not occluded. On the other hand, excessive force causes occlusion of blood vessels, hyalinisation of the ligament and undermining resorption of bone. During this extended compression phase damage to the root surface cementum may occur. Subsequent repair to a greater or lesser extent may occur. Research suggests that all orthodontic treatment is accompanied by some root resorption. It is the greater resistance of cementum than bone to resorption which minimises root resorption and allows the tooth to move. However as force levels and duration increase, hyalinisation of the periodontal ligament becomes more pronounced and cementum resorption increases to more than microscopic levels without the opportunity for running repair.

Mediation of the cellular response of the periodontal ligament and bone to mechanical stress is not well understood although immunohistochemical techniques have significantly extended our insights. Orthodontic forces produce distortion of the peridental tissues causing neuropeptide release from afferent nerve endings inducing

the release of prostaglandins, growth factors and cytokines that affect the apposition and resorption of bone. Lowney et al (1995) have shown that the cytokine tumor necrosis factor (TNF) is an important modulator of bone resorption. Bartold et al (1994) examined the role of neurotransmitters in the inflamed periodontium, including substance P, released from sensory nerve fibres in the periodontal membrane as a result of external stimulus. Substance P has been identified as a neurogenic mediator of the inflammatory response. It increases vasodilation and vascular permeability. The evidence suggests that substance P plays an important role in the regenerative–reparative process. Yousefian et al (1995) demonstrated significant and opposite effects of positive and negative hydrostatic pressures on the production of prostaglandin E (PGE) and cyclic AMP (cAMP) in periodontal ligament cells in vitro. They concluded that the responses mimic those seen in vivo in response to tensile and compressive forces in the periodontal ligament.

Root resorption does not only occur as a response to excessive force. Some patients and families show a predilection to idiopathic resorption even with normal force levels. Orthodontic history taking and x-ray analysis should always pay close attention to the possibility of a pre-existing condition or family history. Any signs of an abnormal apical outline or an indistinct periodontal space or lamina dura should be noted and drawn to the patient's notice. If there appears to be any likelihood of resorption the patient or parent will need to understand the relative benefits of treatment. If there is any further resorption treatment may be terminated. Where teeth are driven into the cortical plate as may occur with excessive labio-lingual tipping or rapid maxillary expansion, significant root resorption becomes more likely. A history of trauma is also recognised as a factor which sensitises a tooth to root resorption during orthodontic treatment as well as causing a deterioration of the vitality of the pulp with possible discolouration.



(a) *(b)*

Fig. 2: (a) Idiopathic root resorption of most upper teeth in a patient aged 14 years. (b) There was a family history of the condition which was apparent in the younger sister.

The forces used to move teeth must be related to the *en face* root surface area. This is the surface area presented on the compression side of the tooth and will vary enormously with the particular movement. For example the *en face* surface area on the mesial surface of a lower incisor is of the order of $0.5cm^2$. However, the *en face*

surface area on the lingual is only 0.2cm^2. The force used to move a tooth must, therefore, be related to the direction and type of movement. The *en face* surface area on the distal of an upper canine is about 1.0 cm^2.

Removable appliances are basically capable only of tipping movements which require a minimum of force. Even the distal tipping of an upper canine, which is a relatively large tooth, requires a force of no more than 60 grams. Upper incisors may be tipped with forces as low as 20 grams per tooth. Ricketts et al (1979) have emphasised the importance of matching forces to the tooth and the movement to be achieved. Even the depression of four lower incisors requires no more than 60 – 80 grams of total intrusive force. Complex forces, including bodily movement and torquing of roots, do not require significantly higher values of force per unit of root surface area.

TYPES OF TOOTH MOVEMENT

The concepts and laws of biomechanics in orthodontics have been revolutionised by the work of Burstone (1994) and associates over the last thirty years or so drawing attention to the importance of control of the centre of resistance and centre of rotation in calculating the responses of a tooth or group of teeth to orthodontic forces. An object floating in space (unrestricted by gravity or friction) has a centre of mass. A force applied to the object directly through the centre of mass cause pure translation without rotation of the object (Fig. 3 a,b). As the application of the force moves away from the centre of mass, translation and rotation are induced at the same time. As the force moves further out from the centre of mass the rotational effect increases relative to the translational effect.

The clinical equivalent of the centre of mass in orthodontics is the centre of resistance. It is the point through which an applied force would cause translation only. Because the centre of resistance lies at about 4/10 of the distance from the gingival margin to the apex, it is impossible to apply a mesio-distal or lateral force to the tooth directly through the centre of resistance. In practice, to achieve translation without tipping a complex equivalent force is required.

A moment is defined as a measure of the tendency to produce rotation. Assume a tooth is to be moved lingually with a single simple force of 100 grams applied to the bracket which is 10 millimetres from the centre of resistance. This force will induce a moment of 1000 (100 x 10) g/mm and conventionally this is termed a negative moment i.e. – 1000 g/mm. This moment will move the crown lingually and the apex labially around a centre of rotation which is not the same as the centre of resistance. To counteract this moment a compensating positive moment of + 1000 g/mm is also applied at the bracket at the same time. Thus a force of 100g plus a positive compensating moment of + 1000 g/mm are equivalent to a 100g force through the centre of resistance and give translation without rotation. By varying the balance between the induced and compensating moments the centre of

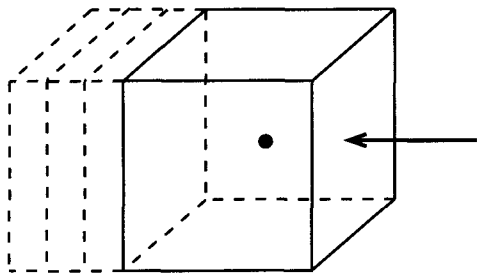


Fig. 3a: A force directed through the centre of mass causes pure translation in the absence of gravity and friction.

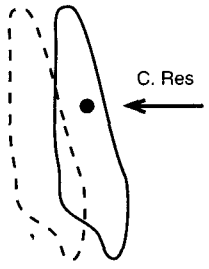


Fig. 3b: A force directed through the centre of resistance of a tooth causes translation without tipping or rotation.

rotation is varied and greater or lesser relative movements of the incisal edge and the apex are achieved. When the force is applied without any compensating moment then pure uncontrolled tipping is generated and this occurs around a centre of rotation at about the junction of the middle and apical thirds of the root (Fig. 4). This is the type of movement caused by the simple force generated by removable appliances. Where a number of teeth are tied into one block (e.g. four incisors) the centre of resistance becomes a composite of all four.

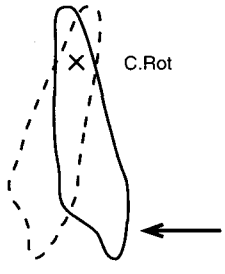


Fig. 4: Tipping around the centre of rotation caused by a simple force as applied to the crown by a removable appliance.

In practical terms and selecting a relatively simple example such as the upper canine certain assumptions are required. If the average distance between the bracket position and the centre of resistance is 11mm then a moment to force ratio of 11 (M/F =11) is required to ensure bodily movement (translation) of the tooth (Fig. 5). The achievement of a constant and predictable M/F ratio over the entire range of a spring is exceedingly difficult and depends not least of all on the properties of the material from which the spring is constructed. Conventional fixed appliance stainless steel spring designs such as the vertical loop are unpredictable. Burstone has shown that at 1mm of activation the initial M/F ratio of 5 may be acceptable but causes tipping movement. As the spring deactivates by only 0.5mm or so the M/F ratio may rise rapidly to a value of 20 or more causing excessive root torque. The newer beta titanium alloys allow a more constant M/F ratio over a good range of activation with predictable root movement. However, clinically they can be very difficult to manage. Gjessing (1985) designed a stainless steel spring which gave a predictable M/F ratio. Perhaps the most predictable (and slow) method for parallel bodily movement is to slide the firmly ligated tooth along the arch wire with the proviso that the arch wire must not become "bitten out" inadvertently inducing an undesirable moment on the tooth – a very common occurrence in the lower arch. These considerations do not apply directly to removable appliances but highlight the need to vary appliances to suit the objectives of treatment.

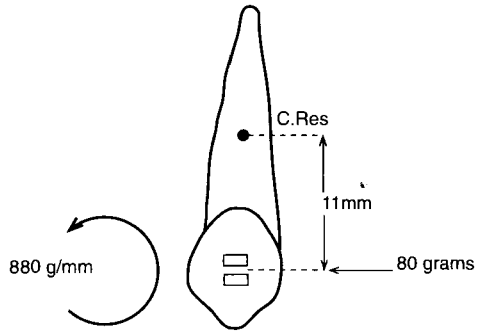
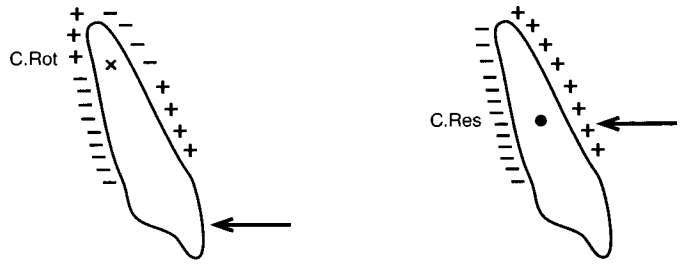


Fig. 5: A force of 80 grams applied to the bracket lying 11 mm from the centre of resistance requires a compensating moment of 880 gram/millimetres to achieve translatory tooth movement (M/F=11).

Tipping movements with removable appliances require minimal force. The tooth will tip around a centre of rotation at the junction of the middle and apical thirds of the root. Areas of compression and tension occur on both sides of the root. Compression occurs apical to the centre of rotation on the same side as the force and occlusal to the centre of rotation on the opposite side to the force. The converse applies to areas of tension. Because of the locus of the rotation centre, the crown will travel relatively greater distances than the apex. One practical consequence of tipping is that the axial inclination of the tooth relative to the occlusal plane may be markedly altered in some cases such that appearance may be compromised by the abnormal inclination of the tooth. In addition, lingual tipping of protruded incisors

causes elongation relative to the occlusal plane. Labial tipping of teeth in crossbite causes elevation of the edge relative to the occlusal plane.



(a) (b)

Fig. 6: (a) A simple tipping force applied to the crown causing rotation around the centre of rotation with areas of bone resorption and apposition on both sides of the root (b) a complex equivalent force acting through the centre of resistance allows bodily movement with bone resorption only on one side and apposition only on the other side of the root.

ROOT TORQUE

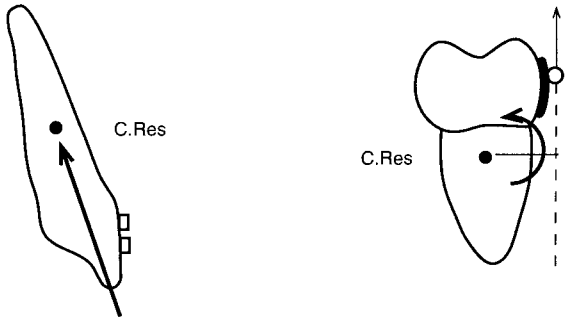
Excessive tipping may be corrected by a torquing movement of the tooth where the centre of rotation lies in the crown of the tooth with little crown movement. This requires bone resorption along the entire root surface. Root torque cannot be achieved with a simple one point contact force. A complex couple (force plus compensating moment) is required to move the root and at the same time restraining the crown to its present position. In practice, combinations of tipping, translation and root torque are employed depending on the initial angulation of the tooth. If the tooth is at a normal angulation before it is retracted then translation is required. Alternatively the tooth may be first tipped and later uprighted or torqued. Angulations of teeth also affect interdental relationships and where angulations depart significantly from normal values, interarch articulations become disturbed.

EXTRUSION AND INTRUSION

Extrusion from the socket in the alveolar bone may be required to allow restoration of a tooth which has been fractured sub-gingivally. Because there is no direct *en face* root surface the only bony reaction required is deposition. This movement requires very little force and its range should be strictly limited so that there is no chance of moving the tooth ahead of the capability of the periodontal tissues to form new bone – about 1mm per month. This movement may be undertaken using either removable or fixed appliances. The removable appliance is designed with a hook opposite another hook cemented or screwed into the fractured tooth. A piece of elastic thread is then tied between the two hooks. It is important to ensure that

there is sufficient space for the root fragment to move. Where the fracture occurred some time previously, the adjacent teeth may have closed over the root fragment so impeding its extrusion. For this reason there may be a need for some preliminary space opening.

Theoretically direct axial intrusion requires frontal resorption of bone on all surfaces of the lamina dura (Fig. 7). In practice, the force is rarely directed in a true axial direction and usually involves some tipping, thus leading to areas of apposition and resorption. Importantly, heavy forces are not required to achieve intrusion. The force system must again involve a couple because the point of force application is usually on one side of the crown. A vertical one point contact force on either the labial or lingual will have a resultant apicoincisal rotational effect.



(a) (b)

Fig. 7: Direct axial intrusion requires a force acting through the centre of resistance. If the force is applied to the bracket a rotational moment will be induced unless a compensating moment is also applied (b) axial rotational moment induced by an extrusive force at the buccal tube and causing lingual crown roll.

Interestingly, extrusive mechanics on lower molars by means of tip back or anchor bend in the arch wire passing through the buccal tube may have a pronounced lingual rolling effect because the extrusive force is being applied buccal to the centre of resistance, setting up an apico-occlusal rotational moment around the centre of resistance.

ROTATION

Crown rotation occurs around the apico-incisal axis of the tooth. Pure rotation without translation requires a force couple to produce rotation only (Fig. 8). No tooth is perfectly round in cross section and the rotational couple will result in a combination of compression and tension areas in the periodontal membrane with bony resorption and apposition. Tooth movement causes stretching of the fibres of the periodontal membrane and derotated teeth are subject to rotational relapse.

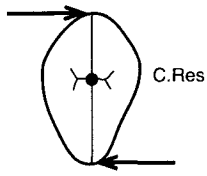


Fig. 8: Crown rotation without translation requires a couple. A force applied to one side only causes translation and rotation.

PAIN

The application of force during orthodontic treatment will usually result in a period of discomfort but pain should be minimal. In practice the threshold response varies markedly from one patient to another and even seems to vary for the same patient from time to time. Interestingly, some patients experience significant pain upon the release of forces as occurs when arch wires are removed at an adjustment appointment. The pain diminishes on the re-application of the force in the same direction. This would suggest that tissue fluid pressures within the ligament mediate the pain response.

In general terms, excessive force causes more pain than optimal force. Pain usually develops soon after appliance adjustment and lasts for 24-72 hours. Headgear forces which may be as high as 400 grams in some cases do not seem to cause notably high levels of pain in young patients but headgear wear is often associated with short intermittent periods of pain which do not continue with continued headgear wear. If pain due to any appliance becomes protracted the force levels should be reduced or the patient instructed to leave the appliance out for a few days until the condition settles. Where pain persists in spite of sensible remedial action, either a pulpal or periodontal lesion might be suspected. The particular tooth should be checked radiographically and tested for vitality and the colour and opacity with transmitted light checked carefully. Pain caused by the forces generated by removable appliances are minimal although a patient will sometimes remark that sensitivity to pressure is noticeable when a tooth is moving. Pain thresholds in adults are noticeably lower than in growing children. While children may experience some discomfort or pain after initial placement of the appliance, it is rarely significant after the first appointment. Some adults, on the other hand, may experience considerable pain after each adjustment throughout treatment – this effect is more noticeable with fixed than removable appliances.

Continued pain in individual teeth during orthodontic treatment should be watched closely. The vitality of the tooth should be investigated. A re-examination of the dental history may reveal a traumatic episode – not infrequently this occurs during treatment. When teeth are under active treatment even a relatively minor blow, such as from a tennis ball, may cause a significant reaction. A pre-treatment history of trauma should always be elicited before placing appliances. Such teeth are subject to loss of vitality and, more rarely, pulpal pain during treatment. They may show

root resorption during treatment. Clearly, the patient should be warned. Idiopathic loss of vitality during treatment occurs infrequently. But even in these cases trauma should still be suspected. School dentists and endodontists report that many children are reluctant to reveal a traumatic episode to either the parent or the dentist because they do not want to be subjected to the inconvenience of going to the dentist.

ROOT RESORPTION

Some root resorption probably occurs in most instances of orthodontic tooth movement but subsequent repair leaves no significant lasting damage. However, occasionally marked root resorption will occur. Root resorption requires resorption of cementum and dentin. Permanent shortening of the root length decreases the crown/root ratio and theoretically makes the tooth more easily displaced by force. The literature is remarkably sparse on the matter of tooth loss associated with orthodontic root resorption. Careful examination of x-rays may reveal evidence of root resorption prior to treatment. In such cases, the severity of the malocclusion will be a factor in the final decision for or against treatment.

The main factors influencing root resorption are inherent susceptibility, level of force, duration of force and type of force. Evidence suggests that higher force levels produce more root resorption and the longer the force is applied the greater will be the resorption. Resorption also seems more likely with root torque forces applied over prolonged periods and with excessive moments or M/F ratios. With fixed appliances most of the stainless steel arch wire mechanisms used to retract teeth are limited by the load/deflection characteristics of the wire or the force of elastics, although some multi-loop designs are capable of exerting high forces over a long range. The newer titanium alloys should be activated carefully to ensure that force levels and M/F ratios are within physiological limits and that the continuous long *range of action does not endanger the periodontium.*

PERIODONTAL DAMAGE

The question of periodontal damage due to orthodontic treatment is problematical. Some claim permanent loss of crestal bone or attachment. However, the work of Alstad and Zacchrisson (1979) and Polson and Reed (1984) suggests that periodontal damage and gingival recession are not significant issues, if reasonable gingival health is maintained during treatment. On the other hand continued treatment in the presence of significant periodontal disease may lead to further damage and hyperplasia. In the presence of a severe malocclusion the operator is sometimes faced with a choice between possible damage to the periodontium and no orthodontic treatment. In spite of every effort in some cases, little improvement in periodontal health can be achieved, by either orthodontist or periodontist. Where the oral environment, such as gingival exposure, encourages gingival inflammation it may be very difficult to restore periodontal normality prior to the treatment of the malocclusion.

ANCHORAGE

Anchorage is the base from which a force is exerted. Forces applied to move a tooth induce reciprocal forces which tend to move the anchorage units in the opposite direction. In the case of removable appliances, anchorage is supplied by the anchor teeth and the soft tissue contact of the appliance with the mucosa. The slope of the palate and the lingual alveolar morphology in the mandible give removable appliances enhanced anchorage. Mostly an attempt is made to limit the reactive movement of the anchor teeth. However, where excess space is available, forward movement of the anchor teeth may be encouraged.

Anchorage is composed of units of resistance which may come from one tooth, groups of teeth, mucosal contact and occasionally from extra-oral structures. We may classify anchorage on the basis of the anchor unit and the type of tooth movement to be accomplished. Simple anchorage is available where the anchor teeth are allowed to tip, as with removable appliances. Simple anchorage may be:

1. Single – where one tooth with a greater root surface is used to move a tooth with a smaller root surface area,

2. Compound – where multiple teeth with a greater root surface area are used to move one or more teeth with a smaller root surface area.

Axially controlled anchorage is available when the anchor teeth are not permitted to tip and thus offer greater frontal root surface resistance. If the teeth move they must move bodily. Sved capping over the lower incisors attempts to limit the tipping response. In reality, true stationary anchorage cannot be achieved absolutely as the anchor teeth will always move to some extent – unless otherwise supported. However, groups of teeth tied together and prevented from tipping may provide effective axially controlled anchorage if the force levels per anchor unit are kept low. Reducing the number of teeth to be moved at any one time also helps to reduce movement of anchor teeth.

Reciprocal anchorage is that anchorage obtained when the force applied results in equal movements of the tooth or teeth on both sides of the space. The common example is closure of a maxillary mid-line diastema by equal movement of both central incisors with one pulling against the other. Reciprocal anchorage may be either simple with tipping or axially controlled without tipping.

Reinforced anchorage is any type of anchorage which is reinforced by another type of anchorage. The most common forms of reinforcement are inter-maxillary elastics and extra-oral traction with a headgear. The sources of extra-oral anchorage, which may be used to reinforce intra-oral anchorage, may be either cervical or occipital, being derived from the back of the neck or the back of the head. Practical methods of reinforcing anchorage with removable appliances include:

1. Reduce the number of teeth to be moved at one time.
2. Reduce the force so that the reciprocal force per anchor unit has little effect.
3. Ensure an accurate fit and maximum mucosal contact area.
4. Limit tipping of the anchor teeth with a labial bow or acrylic capping.

RETENTION

Relapse is the movement of teeth toward malpositions after the completion of active treatment. Sometimes relapse may be encouraged where a tooth has been purposely over-corrected. Most relapse is not encouraged. Retention and relapse are related parts of one of the most vexing problems in orthodontics. How do we guarantee stability of the corrected occlusion? Retention is the process of holding the teeth in their corrected positions until stability is achieved. The definition may be ephemeral, in that stability over the long-term may never be obtained. This does not mean that orthodontic treatment will be followed by relapse to the original condition. However, the practitioner must realise that the concept of an unchanging occlusion is false. Many factors continue to influence inter-arch and intra-arch relationships including the soft tissues, the periodontium, eruption of third molars, occlusion and function.

After orthodontic treatment, the periodontal tissues require time to reorganise and consolidate in order to reduce the possibilities of relapse. The supracrestal tissues, in particular, require long periods to overcome the effects of treatment. All orthodontic treatment is followed by some rebound during retention and this has led to the principle of overtreatment prior to retention. Overtreatment of overbite and rotations is particularly advocated as an aid to maintenance of corrected positions. Some authors claim that with correct diagnosis and treatment, the teeth should finish in a self-sustaining balanced position in harmony with the soft tissues and with one another. Most practising orthodontists would not subscribe to this view after the experience of prolonged and detailed efforts to overcome the problems of relapse. Relapse is not an absolute term and varies in degree from minor to severe. Very few treated cases show no relapse. Most cases will show some relapse over the period of continued development of the occlusion including the eruption of third molars. Relapse becomes more significant in the less severe cases because the degree of improvement obtained with treatment is small. Any relapse is therefore relatively more noticeable.

Having gone to some trouble to emphasise that perfect stability can never be achieved after treatment, certain principles of retention have emerged. The appliances used most frequently are the upper Hawley retainer and the lower lingual arch. Many variations in design have been advocated. Irrespective of the design, no appliance will be satisfactory if it is not worn as instructed. Compliance with retainers is a considerable problem and many children decide for themselves not to cooperate. The difficulty is exacerbated in that parents are often unaware that the appliance is not being worn. Once the relapse occurs it is often seen as the fault of the clinician in spite of clear instructions.

Where there have been multiple tooth movements, as in the treatment of a Class II division 1 case, it is usual to wear the retainer full-time for about 9 months. After this time the period of wear may be reduced to night only, being worn from approximately 7:00pm until 7:00am for a further 9 months. Eventually the patient begins to leave the appliance out for 2 days at a time, checking for any relapse and tightness of fit after not being worn. Where the teeth become firm in a shorter time, these arbitrary periods may be reduced to suit the particular case. Where teeth are firm to pressure and percussion, the clinician may feel more confident about the cessation of retention. With the introduction of ultra-thin thermo-formed retainers prolonged half time retention has become more of a practical possibility for many patients. This is particularly so for adults who have gone to considerable personal trouble to undertake treatment and are not easily convinced that relapse is something simply to be accepted.

Certain conditions, such as rotations and excessive axial tipping, are very prone to relapse with recurrence of the rotation or original inclination. Similarly, buccal segments that are not correctly occluded at the end of treatment are likely to subsequently relapse with recurrence of overbite and overjet. One of the most important aids to retention is over-correction. Rotations and root angulations should be over-corrected. The over-correction of buccal segment relations is also a good idea. Buccal crossbites should be over-expanded by about half a tooth width with the expectation of some relapse.

PERICISION (FIBRECTOMY, FIBREOTOMY)

Another useful adjunct to the retention of corrected rotations is the supra-crestal fibrectomy. Reitan (1959) demonstrated that the supracrestal periodontal fibres without direct bony insertion may remain stretched up to 9 months after derotation. Edwards (1968, 1970) introduced the procedure of fibre resection to reduce relapse. In patients without periodontal infection or defects, pericision does not cause any significant lasting deleterious effect. It involves severing the stretched free gingival fibres of the periodontal membrane. The procedure is simple, causing minimal distress to the patient. Fibres around the complete circumference of the tooth are severed. The gingivae may appear quite contused but this disappears within 48 hours. Without this procedure, many rotations will relapse – even with over-rotation and prolonged retention. The tooth should still be held by a retainer until a period of periodontal healing and consolidation has elapsed.

LOWER INCISORS

One of the most vexing aspects of retention is the gradual crowding that occurs in the lower incisor region in some cases during the late teens and early twenties. One important cause of this problem during orthodontic treatment is expansion of the lower intercanine width. However, even with extractions and in the absence of

canine expansion, the problem may occur.

Some researchers have implicated the eruption of third molars as a cause. In some cases, crowding will occur even when third molars have been removed. There can be no doubt that third molars are contributory and cannot simply be dismissed. Occlusion in the growing patient and young adult is in a state of flux. In some patients, the continuing changes are quite evident while in others they are minor. During these years, abnormal or undesirable forces may destabilise the occlusion further and cause crowding. It is not acceptable to subject a child to several years of orthodontic treatment and simply dismiss the third molars as of no consequence. If they do not have sufficient space to erupt correctly, they should be removed or kept under observation. Lower arch retention should be continued until they have been accounted for if there is any sign of crowding or relapse.

The idea that third molars should be left until they cause trouble is unacceptable. Careful observation of orthodontic patients shows that nonextraction treatment frequently leads to crowding and not only results in a space shortage for the third molars but for the second molars as well. Ricketts et al (1979) have confirmed that the likelihood of successful eruption of third molars increases by 30-70% where bicuspids are extracted.

Prolonged retention with a lower fixed lingual retainer wire may be a further aid to long-term stability. This is continued until a final decision regarding third molars has been made. Although not widely used by orthodontists, experience with fixed lower 6-to-6 retainers shows that they overcome the problems associated with virtually every type of retainer. They hold the critical lower arch length and significant rotational or crowding relapse during wear is rare providing the usual precautions during treatment have been taken. Occasional loosening is easily checked by the patient and recementation is done at a time convenient to the patient and orthodontist. Alternative designs such as lower 3-to-3 or 4-to-4 retainers are not as reliable and slipped contacts are common with their use. Bonded lingual retainers on multiple teeth offer an alternative but the inevitable inconvenience associated with broken bonds and ultimate debonding make them less attractive than they appear superficially. In some instances the removal of lingual bonded retainers can be very difficult particularly where multi-pad types are employed.

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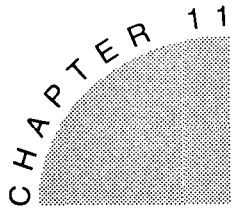
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PRINCIPLES AND MANAGEMENT OF REMOVABLE APPLIANCES

PRINCIPLES

The term removable appliance in the present context includes those appliances which are designed to move or maintain the teeth in one arch only and are removable by the patient. It does not include functional appliances which rely on the forces generated by the musculature and are usually designed to achieve reciprocal effects in the upper and lower arches at the same time. While the distinction between the two groups is not always clearcut, appliances based on springs, wires and screws can be usefully considered in a separate category.

Retention is the resistance to displacement of the appliance away from the fitting surfaces of the teeth and soft tissues and is usually achieved by engaging undercuts on the teeth with retainers. Significant retention is also achieved by means of adhesion between the acrylic base and the palatal mucosa by medium of the saliva. In most instances removable appliance retention in the upper arch depends on the the Adam's crib. This device does suffer disadvantages in the lower arch in some cases because of lack of positive retention areas on the buccal surface of lower molars in particular. Lower removable appliance retention may be better obtained using circumferential clasps or ball clasps if difficulties are encountered.

The stability of an appliance is in part related to retention. But stability is also affected by the basic design of the appliance. Where wires interfere with the occlusion of the opposing teeth the resulting interferences will be a cause of instability even if the retention is quite good. If a posterior or anterior bite plate causes uneven or unbalanced contacts against the opposing teeth, this may cause instability which breaks the retention of the clasps. Retention may be considerably enhanced by designs which do not cause interfering occlusal contacts.

While the same teeth may be used for retention and anchorage these two functions are not directly equivalent. Generally all or most teeth in the one arch are included in the design to provide better anchorage without necessarily adding significantly to the retention of the appliance. Conversely, forces generated by active components may affect retention. For example where a spring acts against an inclined tooth surface such as the mesial aspect of a canine, it will generate a downward component which will tend to displace the appliance.

The forces supplied by springs and screws should maintain the vitality of periodontal structures and avoid undermining resorption. Forces in excess of the optimum

required to move teeth may diminish anchorage because the force per unit in the anchorage segments is more nearly optimal for tooth movement. Optimal force levels will vary with the root surface area on the resorption side – the 'en face' area. With upper canines this will be relatively large while for lower incisors it will be small. Tipping forces delivered by springs should not exceed 20-30 gm/cm^2. Forces delivered by screws are intermittent and a screw should not be opened faster than the capacity of the tooth to move at a physiological rate usually about 1.0-1.5mm per month depending on patient compliance.

The design of any removable appliance should consider the following factors:

Activation – the active range of components should eliminate the need for frequent visits.

Anchorage – the appliance should engage sufficient teeth to optimise anchorage for the individual patient.

Appearance – may be a major factor for some patients, particularly adults who must perform their usual duties in the office.

Bite opening – may require the incorporation of a bite plane.

Comfort – comfort levels should encourage the patient to wear the appliance. An appliance may be superbly finished in the laboratory but may be uncomfortable if over-extension causes ulceration.

Cost – production costs may be a major consideration in private practice when breakage or loss requires replacement.

Iatrogenic damage – the appliance must be designed to eliminate damage to either hard or soft tissues.

Manipulation – the appliance must be relatively easy to manipulate and a design which is inherently complex will be more likely to fail. For example multiple springs are not advised if the patient cannot manage them.

Retention – may be improved by incorporating sufficient retention devices and this will usually add significantly to the comfort of the appliance.

Stability – an appliance may have good retention but be inherently unstable because of interference with occlusion or mandibular excursion. Similarly an appliance may have very little retention but be inherently stable because it does not interfere with the contacts or excursions of the teeth.

Type of movement – basically removable appliances can only tip teeth. Care must be taken to ensure that the line of action of any force is pushing the tooth in the desired direction.

Utility – the appliance must be rugged enough to provide useful service over the expected period of wear. However, over-design is not desirable if it leads to a lower comfort level such as restricted tongue space due to a thick acrylic base.

Removable appliances are able to perform a limited range of tooth movements efficiently. While they have been modified to perform complex movements such as root torque this is more efficiently achieved with fixed appliances. The application of detachable headgear to removable appliances should be discouraged on safety grounds. In the instance where the headgear bow is fixed to the appliance and cannot be detached, there is much less likelihood of a misadventure. Injuries due to headgear may be serious and every effort must be made to minimise the risks.

Removable appliances are commonly used in the following circumstances:

Anterior bite plates to assist bite opening mainly by over-eruption of posterior teeth and therefore generally used in growing individuals.

Retraction of canines or bicuspids in association with extraction of teeth immediately adjacent to the teeth to be moved.

Retraction of the upper incisor segment by means of springs or elastics which retract the four upper incisors together.

Space opening by means of expansion screws which may act on one or more teeth.

Lateral arch expansion by means of an expansion screw acting reciprocally on left and right segments.

Posterior movement of molars and bicuspids to correct a buccal segment relationship.

Lingual or buccal tipping movements of individual posterior teeth.

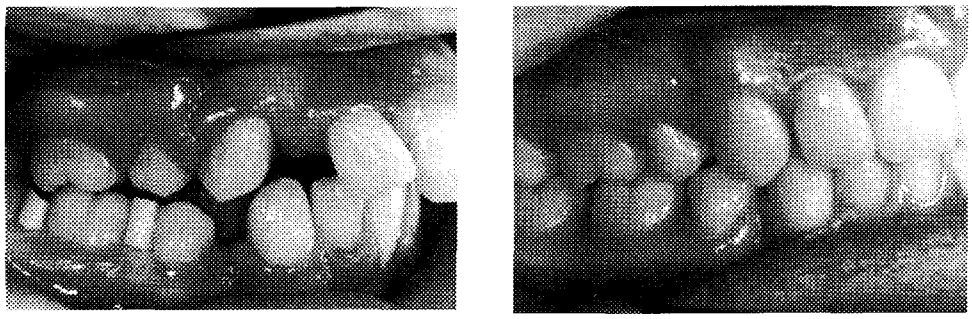
Labial tipping of upper incisors to correct an anterior crossbite.

Retention after fixed appliance treatment

SELECTION OF CASES

Because removable appliances mostly move teeth by uncontrolled tipping, careful case selection must be made. The angulations of teeth must be acceptable after treatment. This applies in both the mesio-distal and labio-lingual directions. If tooth uprighting is necessary after tipping, a force couple is required and this cannot be efficiently achieved with removable appliances in most instances. Removable appliance treatment is most efficient where the pre-treatment angulation is such that pure tipping movement will correct the crown relation and leave the tooth at a

normal angulation. Where teeth are angled normally prior to being tipped they will finish with abnormal angulations and may relapse with some consequent space opening. In some instances pronounced tipping may also lead to an unattractive appearance (Fig. 1).



(a) (b)

Fig. 1: (a) Excessive tipping after canine retraction with a removable appliance (b) same case after uprighting and detailing with fixed appliances.

RETENTION

The Adams crib has been adopted almost universally as the primary means of retention for removable appliances most of which are used in the upper arch. It is usually constructed from 0.7mm hard stainless steel wire although for smaller teeth such as bicuspids it is more conveniently made from 0.6mm wire. The principal of retention with the Adams crib is that the arrowheads will be placed in the mesial and distal coronal undercuts. These undercuts usually lie just below the free gingival margin in children where the clinical crown height is minimal. In adults, continued gingival migration usually exposes these natural undercuts and some care may be required to ensure that retention is not excessive (Fig. 2).

In order to reveal the undercuts on the plaster cast of a young patient, the gingival margins must be lightly trimmed. On fitting the appliance in the mouth, the arrowheads will sit just under the free gingival margin without any trauma. Excessive removal of material on the model may cause trauma to the gingiva or the crib may be active against the tooth. If the arrowhead cannot seat passively into the constructed position, it acts as a spring and actually causes displacement of the appliance. Where a tooth is substantially rotated, variation in design will need to allow for the fact that one of the undercuts may not be accessible. The crib can be used on any tooth including a deciduous tooth. However, the retentive areas available on some deciduous molars and lower first permanent molars may be poor. The Jackson clasp may be useful for gaining retention on deciduous teeth. It is a form of continuous clasp and usually made from 0.6 wire (Fig.2d).

Variations of the Adams crib are numerous and include double cribs bent across two teeth from the one piece of wire. Another useful adaptation of the crib is

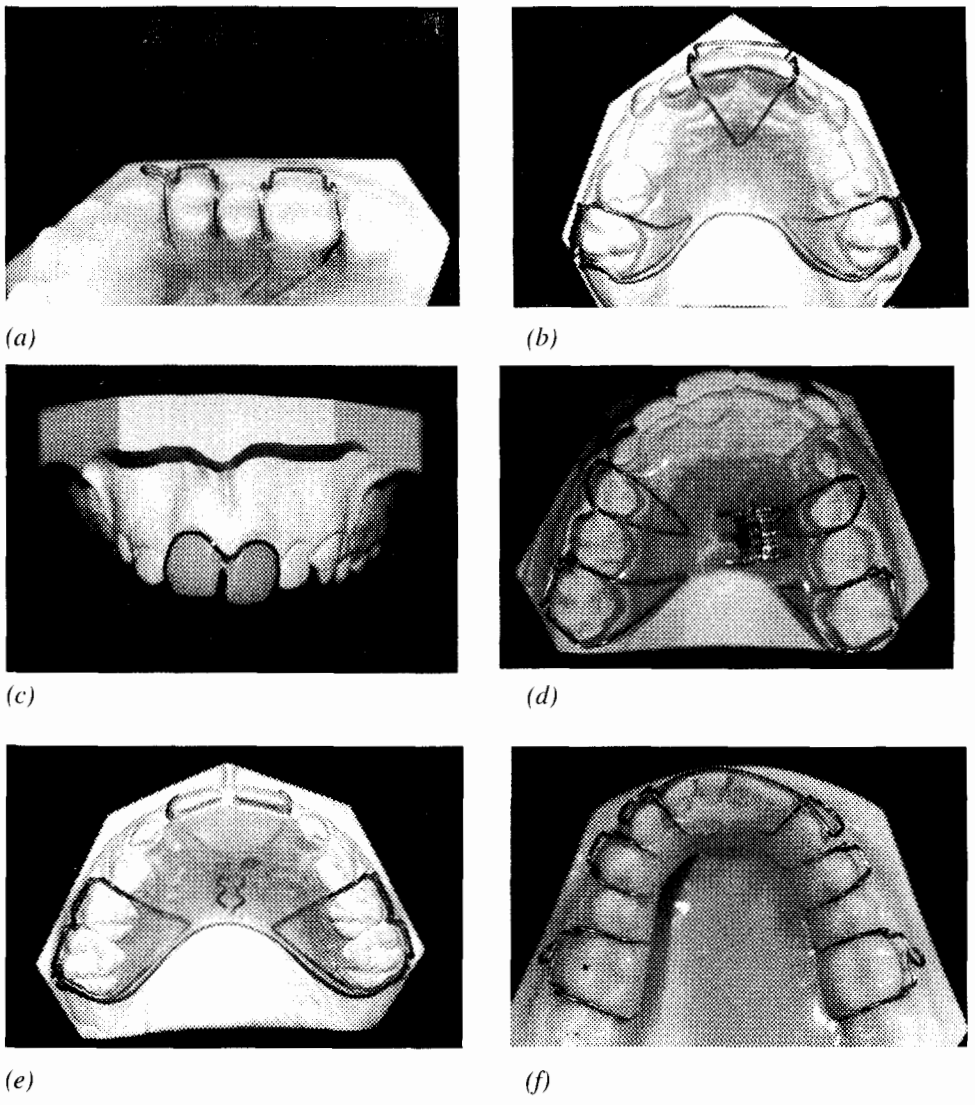


Fig. 2: (a) Standard Adams crib and modified crib with traction hook (b) modified crib engaging two upper central incisors (c) continuous (Southend clasp) over two upper central incisors (d) Jackson cribs on the upper first deciduous molars (e) modified cribs as one piece engaging second deciduous and first permanent molars (f) lower cribs incorporating traction loops in the bridge sections.

constructed across the two central incisors as one tooth. Very good retentive areas are available on the distal line angles of these teeth unless they are markedly retroclined. Occasionally the bridge of the crib, between the arrowheads, must be curved to conform to the arch shape across the two teeth. Some clinicians prefer to use a continuous (Southend) clasp across both upper central incisors made from 0.8 or 0.7 wire. This continuous clasp is more robust and more comfortable against the lips. It adds considerably to the stability of the appliance. It suffers the disadvantage of not being easily adjustable.

It is common for cribs to fracture either at the arrowhead or where the wire enters the acrylic. A fractured arrowhead can be repaired with solder but if the fracture occurs nearer the acrylic, repair is not possible. Usually the whole crib has to be replaced. Sometimes a temporary solution is achieved by cutting the fractured side off completely and bending a small circle in the free end. Probably the most common cause of wire fracture is the practice of flicking the plate up and down with the tongue. This may be done literally hundreds of time a day inducing stress fractures.

Adjustment of the Adams crib during treatment needs to be done with some care in order to ensure firm retention without causing displacement of the appliance. The crib may be adjusted where the arm crosses the occlusion if this has been bent away from the occlusal aspect of the teeth by the patient's pulling down during removal. However, bending the arm occlusally too far will turn it into an active spring causing displacement of the appliance. Adjustment nearer the arrowhead is sometimes required to establish good retention. But excessive adjustment of the arrow head will give too much retention and make removal difficult. In other cases it may cause trauma to the adjacent gingiva or pain due to excessive force against the crown of the tooth. Comfortable adjustment of the Adams crib can sometimes be difficult to achieve – very small adjustments are recommended with checking before adjusting the crib further.

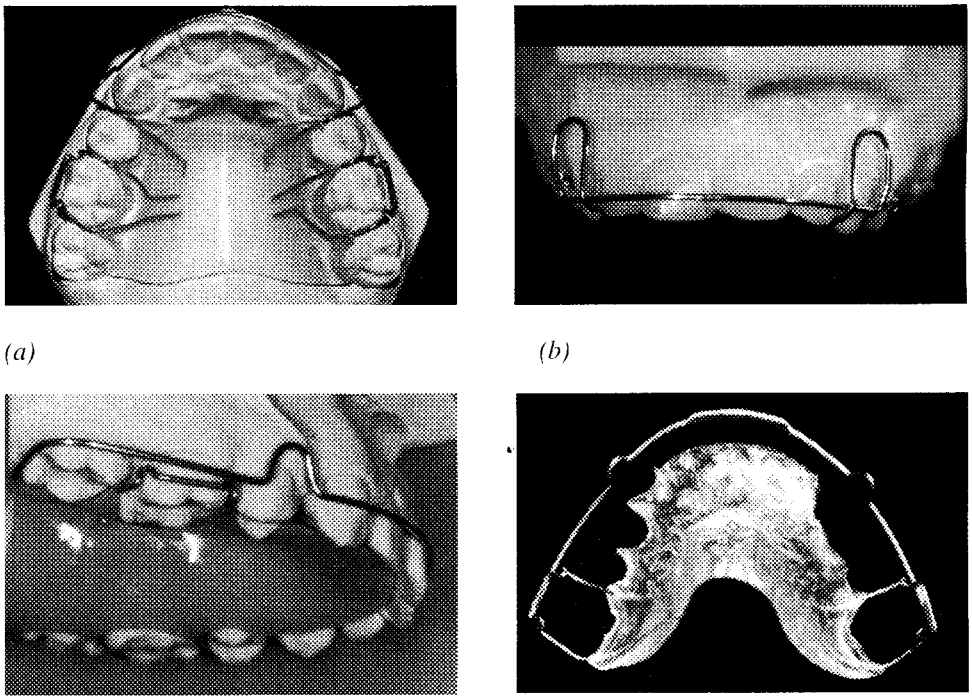
LABIAL BOW

The labial bow is a very important component of many removable appliances and may be used to achieve retention and stability. In some cases it may also be used to move teeth (Fig.3). However, the same labial bow on the same appliance cannot effectively be used to achieve all three functions. A labial bow can improve retention if placed above the undercut of proclined incisors. A well fitted labial bow will also stabilise the appliance particularly where the teeth are firmly held in an accurate fitting appliance with acrylic to the lingual surface and the bow to the labial surface. Generally, a fairly heavy labial bow of 0.9mm is suitable for these purposes. Where the labial bow is used to retract the incisors, more flexibility is required and a wire size of 0.7mm or 0.8mm may be more suitable.

The design of the labial bow may vary and two types are commonly used – the conventional low labial bow and the reverse low labial bow. The reverse bow is constructed with the loop distal to the point where the wire crosses the line of the occlusion. It is useful when a positive stop is required to prevent movement of the lateral incisor as the canine is retracted by means of a spring. Usually the inter-dental fibres will cause the lateral incisor to follow as the canine moves back. The reverse bow is also a useful method of achieving increased flexibility over a relatively short distance from lateral incisor to lateral incisor. When used in cases of first premolar extraction, the reverse loop section may help to guide the canine. The conventional labial bow, sometimes termed the low labial bow, is frequently used on upper retainer appliances and crosses the occlusion behind the canine. If the occlusion is particularly tight in this region, the tip of the lower canine may impinge

on the wire. Utilisation of a bite plate to alleviate the problem is not usually desirable after treatment.

Space consolidation of the whole upper arch is sometimes better achieved by means of a labial bow which does not cross the line of occlusion. The bow commences distal to the last standing tooth, usually the second molar, and passes completely around the arch to the other side. Space consolidation is achieved by means of loops in the second premolar regions. The posterior sections of the bow lie at the level of the gingival margins, while the anterior section is placed at about the middle of the crowns. This design suffers from the disadvantage of interfering with erupting second molars in some cases. Another variant which also allows space consolidation is the soldered labial bow with the bow soldered to the bridge of the Adams crib. These are made from 0.9 wire, are relatively easy to fabricate and do not cross the line of the occlusion.



(a) *(b)*

(c) *(d)*

Fig. 3: (a) Conventional low labial bow and saddle plate (b) reverse low labial bow (c) long labial bow passing distal to the upper molars (d) long labial bow soldered to Adams cribs.

STOPS

Sometimes it is necessary to include wire stops to prevent unwanted tooth drift or to maintain the corrected position of a tooth. Using 0.6mm wire, a simple stop is constructed to rest against the surface of the tooth. The end of the stop is curved into an eyelet to allow ease of manipulation and to prevent soft tissue trauma. This practice should be adopted with all free ends whether on stops or springs.

THE ACRYLIC BASE

The body of a removable appliance is constructed from acrylic resin. Cold-cured resin is used widely. The acrylic base supplies anchorage by reason of its contact with the anchor teeth and the soft tissues. The thickness of the resin must provide sufficient strength and yet not impede normal oral functions. It should be about 2.0 mm thick. The area of coverage will vary with the application, but the wider the coverage the better the anchorage. The edge of the resin should be finished to the gingival third of the clinical crowns of the teeth. The edge of the acrylic should be tapered to the teeth.

Springs are constructed and blocked out with plaster or wax to prevent the resin flowing into the working portion of the spring. After curing the blockout material is removed to give free movement to the arm of the spring (Fig. 6). Special care should be taken to bend retentive tags on the ends of all wires that enter the acrylic so that they will not withdraw from or rotate in the acrylic.

Normally the posterior margin of the acrylic resin is finished just distal to the first permanent molars. Most children will not tolerate much further posterior extension. In addition, the second permanent molars may not be completely erupted. In most cases, there is more or less complete coverage of the palate anteriorly. Occasionally when overbite control and maximum anchorage are not required the acrylic may be trimmed to a saddle shape so that it does not contact the anterior palate or incisors (Fig. 3).

In other instances anchorage may be enhanced by covering a broad palatal area and by covering the incisal edges with Sved capping (Fig. 7). This will tend to limit tipping of the incisors in reaction to forces generated by retraction springs. Sved capping may also be used to prevent over-eruption of teeth or to improve the stability of an appliance.

BITE PLATES

A common addition to the acrylic base is the anterior bite plate also called a bite plane. It consists of an elevated platform designed to occlude with the lower six anterior teeth only and separating the posterior teeth. With time, the preferential occlusion on the anterior teeth leads to overbite reduction by means of over- eruption of the posterior teeth (Fig.4). If the patient is still growing the freeway space re-establishes as the facial height increases. There is very little intrusion of the anterior teeth. This action of the bite plate is desirable in deep bite brachyfacial types but is undesirable in dolichofacial types causing an exaggeration of the underlying vertical excess problem. It should also be noted, that the reduction of overbite achieved with a bite plane is not stable unless the inter-incisor relationships are also changed. That is, the overjet must also be corrected to provide stable contacts between the upper and lower incisors. The final inter-incisor angle should be within normal

limits in order to help occlusal stability. Pre-treatment evaluation of incisor retraction cases must include an assessment of incisor angulations, bearing in mind that removable appliances are limited to tipping movements. If active torque is required this can be achieved more efficiently with fixed appliances.

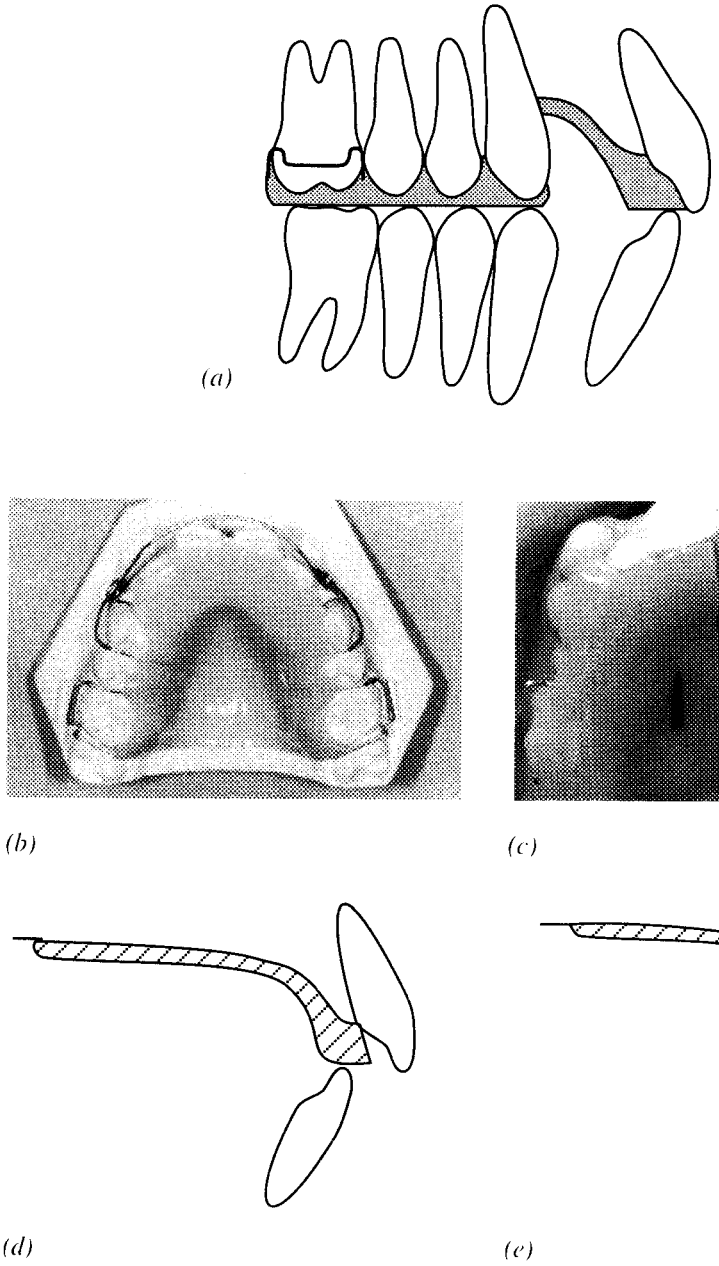


Fig. 4: (a) Schematic representation of anterior and posterior bite plates on the one appliance (b) appliance with anterior bite plate only (c) expansion appliance with anterior and posterior bite plates (d) incorrect trimming of an anterior bite plate prior to incisor retraction (e) correct trimming of an anterior bite plate to clear the palatal tooth surface and the immediate gingival area to allow retraction of the incisors.

The height of the bite plate must not be excessive and should give 2-3mm of posterior separation. Neither should the anterior bite plate extend any further posteriorly than is necessary to occlude with the lower anterior teeth. After adjustment and polishing the bite plate should give a balanced contact on all six teeth. Where overbite is excessive, the bite plate may need to be built up in stages as treatment proceeds in order to continue effective 'bite opening".

The use of anterior bite plates in older patients induces a slower response. Where the patient has completed growth, over-eruption of the posterior teeth will impinge on the freeway space. This may be desirable where there is definite evidence of overclosure and excessive freeway space. Bite opening in adults should not be undertaken without thorough pre-treatment analysis of the occlusion and temporo-mandibular status.

Trimming the acrylic behind the maxillary incisors to allow retraction requires that not only the teeth but also the gingival areas should be relieved. If insufficient acrylic is relieved palatally there may be no movement at all or there may be compression of the attached gingivae (Fig. 4). The acrylic should not be trimmed back too far thus removing the contact for the lower incisors. It is good practice to actually mark the occlusal line of the lower incisors on the bite plate and only remove acrylic anterior to this line. Where an appliance has been worn for some time prior to trimming, the indentations of the lower incisor in the acrylic can be seen. After correct trimming of the acrylic behind the upper incisor teeth, if the patient's head is tilted back, the operator should be able to see a clear space well up onto the palatal soft tissue surface. When the upper incisors are almost fully retracted, the anterior bite plate should be finally removed to allow contact between upper and lower incisors.

A posterior bite plate is used to open the bite to relieve cuspal interferences. It is particularly useful during the correction of both anterior and posterior crossbites where the forces of the occlusion may be acting contrary to the force of a spring or screw correcting the problem. Posterior bite plates should be kept to the minimum required height. They are usually removed as soon as the offending teeth have been moved across the bite. Usually, the posterior bite plate extends from the region between canine and first bicuspid to the last standing tooth. In some cases, it is combined with an anterior bite plate to provide a complete bite platform (Fig. 4).

It is necessary to ensure a balanced occlusal contact of the lower teeth in both centric occlusion and in excursive movements. In adults, where the situation is more demanding, it is advisable to mount the models on a fully adjustable articulator prior to construction. A properly adjusted posterior bite plate may be very thin in some regions, particularly over the cusps. Fracture of these thin pieces of acrylic during wear is of no functional consequence. For best effect these appliances should be worn during mastication.

PRINCIPLES OF SPRING DESIGN

The main mechanism of force delivery with removable appliances is the spring. The design and direction of action of a spring play an important part in obtaining the desired tooth movement. Springs act mesio-distally or bucco-lingually. The principles of design are the same for both types. When a spring is activated to apply a force to a tooth, the force is resolved into two components. One component is at right angles to the surface at the point of contact and the other component is parallel to the surface at the point of contact. The relationship between wire size, deflection and force is given by the formula :

$$D \alpha Pl^3/t^4$$

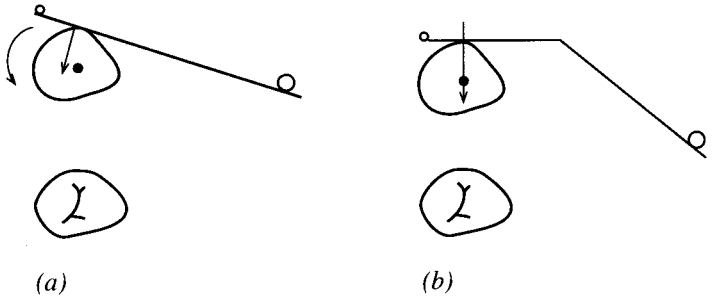
D = deflection, P = force, l = length and t = diameter.

A spring must have a blend of qualities to cope with particular requirements. A palatal spring protected by the acrylic or a guide may be of greater length and smaller diameter (0.5 or 0.6 mm) giving an optimum force over a relatively long range of action and thereby allowing greater intervals between appointments. A buccal canine retractor which is unprotected from the masticatory environment will require a heavier diameter wire (0.7 mm) with a consequential reduction in flexibility and therefore a need to reduce the amount of activation to maintain a physiological force. The buccal spring will also require more frequent adjustments to compensate for both its reduced flexibility and to maintain the correct line of action with the shorter length of the active arm.

Because all springs act along the arc of a circle it may not be possible to maintain the desired direction throughout the total range of action. The problem becomes more obvious as the radius of the spring becomes shorter. An adjustment bend (crank) in the arm of the spring may be required during treatment in order to maintain an acceptable line of action. Where possible, the length should be the maximum possible within the constraints imposed by other factor such as space available, presence of a coil, soft tissue trauma and the stiffness of the wire.

The point of contact of a spring on a tooth may have undesirable effects in both the horizontal and vertical planes. In the horizontal plane the force of the spring should be directed through the centre of resistance of the tooth (Fig. 5). It is often not realised that marked mesio-distal rotations may result from incorrect force application with simple springs. A resolved component of force is generated at right angles to the point of contact with the surface of the tooth. Where the resultant force passes outside the centre of resistance, rotation is induced. In the case of a canine with an elliptical cross-sectional root shape or a bicuspid, lack of care may lead to quite marked rotation on occasions.

The resolved force component parallel with the tooth surface at the point of contact may also cause problems, particularly with excessive activation. For example a spring activated against the sloping mesial surface of an upper canine, may cause vertical displacement of the appliance. In some cases where the retention of the appliance is not overcome by the displacing force, actual intrusion of the tooth may



(a) (b)

Fig. 5: (a) Line of action of spring outside the centre of resistance causing disto-lingual rotation (b) adjusted line of action through the centre of resistance.

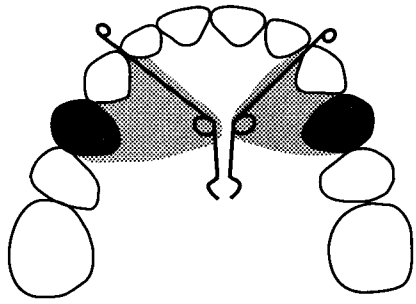
occur during treatment. In contrast where a spring lies above the point of maximum surface convexity, the resolved force may cause the arm to ride up the sloping surface into soft tissues. This can be overcome by means of a palatal wire guide. However, guides are used infrequently and the problem is usually controlled by not over-activating the spring.

The force supplied by a spring must be within physiologically acceptable limits. The force required to tip any tooth rarely exceeds 1 ounce or 30 grams. The ideal spring should be able to deliver the desired force over a long range in order to minimise the need for frequent adjustment appointments. In a cooperative patient, when the spring is correctly activated, time between appointments may be extended to six weeks or so.

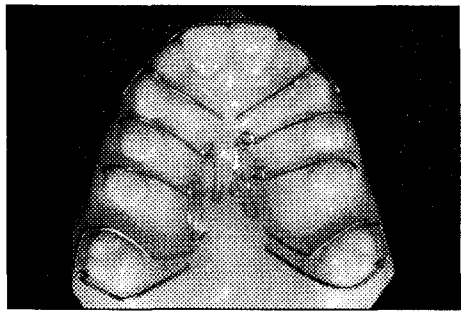
As the length of a spring increases, the force delivered for a given deflection will be reduced. This is the reason why most springs incorporate coils which increase the effective length of the spring. The diameter of wire used has a marked effect on the force delivered. The diameter is kept to a minimum in order to obtain an optimal force over a longer range of action. However, the diameter of wire must also be selected to make the spring robust enough to withstand the conditions in and out of the mouth, (e.g. during cleaning). The deflection of each spring is determined at the time of activation and governs the force supplied. Excessive activation may result in undesirable secondary forces and may also make the appliance difficult to insert.

PALATAL COIL SPRINGS

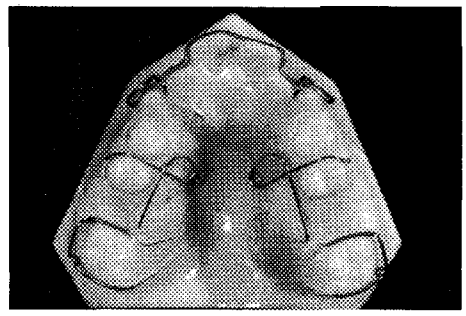
Palatal springs are often used for posterior movement of bicuspids or canines after the extraction of adjacent teeth (Fig.6). They may also be used effectively to retract first permanent molars. The diameter of the spring is usually 0.5mm or 0.6mm wire. A coil is bent at the point of insertion into the acrylic. The coil is about 2mm in diameter. The length of the active arm should be about 2cm with the coil placed well up into the palatal vault and the arm following the palatal curvature. The end of the spring crosses the line of the occlusion as closely as possible and extends buccally around the curvature of the gingiva for 3-4mm so that the patient can easily manipulate it with a fingernail. The end of the spring is finished in an eyelet.



(a)



(b)



(c)

Fig. 6: (a) Zone of action of palatal springs which must be boxed out prior to fabrication to provide unhindered movement of the spring (b) palatal springs to retract the bicuspids (c) modified palatal springs with incorporated guides which allow the active spring section to be left uncovered.

After processing the edge of the acrylic plate adjacent to the extraction space is trimmed to allow movement and to act as a guide to prevent palatal movement. Care must be taken in the design of the spring to ensure that the line of action does not cause rotation. Usually the coil is placed halfway between the starting and finishing positions of the mesial surface of the tooth. With the extraction of second premolars, it will be necessary to retract both first premolars and canines. In this case, springs can be placed on all four teeth in the one appliance. However, they should not initially all be activated at the same time because of difficulty in seating the appliance and the strain on anchorage.

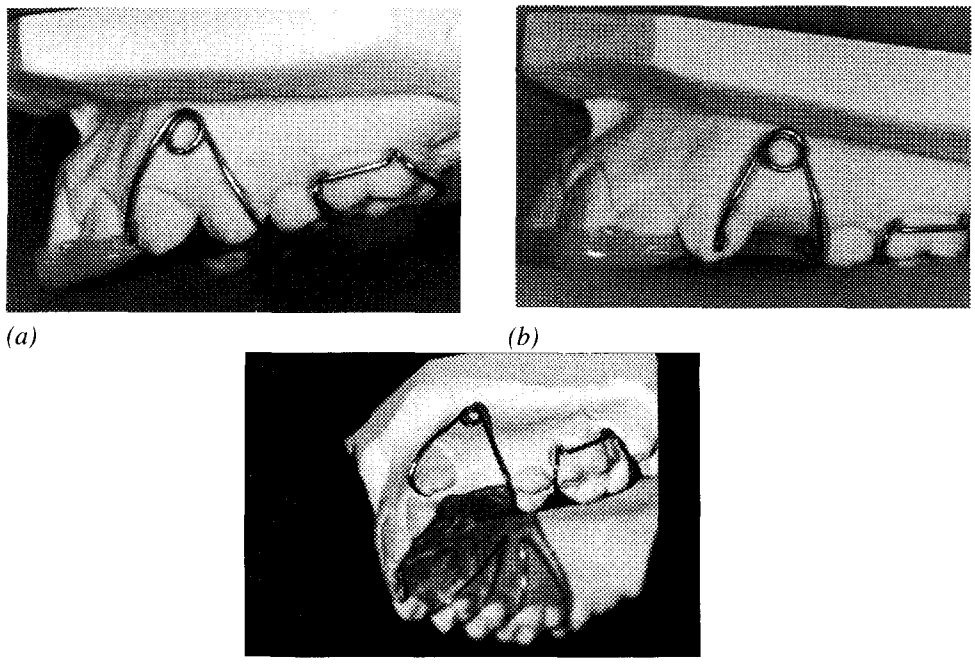
BUCCAL CANINE SPRINGS

Buccal springs are commonly used to retract canines which are high or mesially placed and when a palatal spring cannot be satisfactorily bent to the position of the tooth. The buccal spring is bent from 0.7mm wire in order to resist distortion from mastication (Fig. 7). The wire must be bent close to the labial soft tissues or it will cause ulceration of the cheeks.

The canine spring passes over the line of the occlusion mesial to the second premolar. It must be bent over the contact point as if the first premolar is present, otherwise complete retraction of the canine is not possible, being impeded by the wire. In fact, it is a useful procedure to actually construct and fit the appliance before extraction of the first premolar, in which case the wire cannot pass below the contact point.

The coil should be 3-4mm in diameter and placed halfway between the starting and finishing positions of the mesial surface of the tooth. Activation is achieved by placing the round beak of a pair of spring forming pliers into the loop of the coil and slightly winding the free end further round the beak. There are many variations in finishing the free end of the spring, depending, to some extent, on the initial position of the canine. It may be finished as an eyelet at right angles to the line of action. It may be curved around the crown and fitted to the mesial and buccal surfaces to provide lingual as well as distal movement of the canine.

Placement of the coil and the length of the arm of the spring are governed by the soft tissue reflection of the sulcus. It is difficult to make the length of the arm more than about a centimetre without potential ulceration. Often a distinct muscle insertion can be seen in the region of the first bicuspid and this may require a deviation of the distal arm to avoid the insertion.



(a) (b) (c)

Fig. 7: (a) Buccal canine retractor in 0.7mm wire. The appliance also incorporates Sved capping (b) retractor activated about half the width of the tooth (c) modified canine retractor with curved end to move tooth distally and lingually.

In practice, it is difficult to maintain the ideal relationship between the position of the tooth and the mesial arm of the buccal spring as the tooth moves, and continuing

adjustment of the direction of the spring is required to prevent unwanted movements such as elongation or depression. This highlights one of the problems associated with these springs – they may be difficult to activate satisfactorily if the initial position of the tooth is too far displaced from the line of the arch. However, in such circumstances, a palatal spring is not satisfactory either. With the ready availability of bonded attachments it may be easier to bond an attachment such as a button on the tooth and bend a hook into the appliance to which is attached an elastic. Ideally the bonded attachment should be well to the distal of the tooth to be moved or it will cause considerable rotation.

RETRACTION OF INCISORS

After retraction of the canines, retraction of the incisors is the next step. The variations in appliance design are numerous – usually an indication that no one design is totally satisfactory (Fig.8). The aim is to not only retract the four incisors but to maintain the general anterior arch shape by correct trimming of the lingual acrylic to form a template.

Roberts' retractor – the Roberts' retractor is constructed of 0.5mm wire which achieves excellent flexibility and range of action but is obviously prone to damage. For this reason the section on each side distal to the coil is sheathed in tubing of 0.5mm internal diameter. This is achieved by sliding the section of tubing over the distal arm while it is still straight and then bending the tubing with the wire inside it. The disadvantages of the appliance are its tendency to be easily damaged along with the difficulty of fabrication and the virtual impossibility of repair if the retractor section breaks.

Labial bow – the labial bow passes distal to the canine and mesial to the bicuspid. The loops are approximately 6-7mm wide. This design does not give enough flexibility for substantial incisor retraction but is very useful for closing small spaces and for gathering the incisors to the desired arch shape as determined by the curvature of the labial bow and the lingual acrylic.

Elastics – elastics may be used to retract the incisors by attachment to traction hooks in the region of the canines. While they are useful in patients who object to the appearance of a wire across the incisors, elastics are often difficult to control in terms of direction. Traction hooks may be bent or may be formed by cutting and bending a labial bow after construction. The main disadvantages of elastics are a tendency to slide up the labial surfaces of the teeth on to the gingivae and lack of a passive shape to mould the incisors as does a shaped wire. Most dental offices carry a range of pre-cut elastics, so that varying sizes may be selected to suit different cases in order to achieve the desired force. After complete retraction of the incisors, elastics cannot be made passive and the same appliance is not suitable for passive retention.

Split labial bow – this device may be formed in two separate pieces or by bending a labial bow of the appropriate design for the particular case and then cutting it at

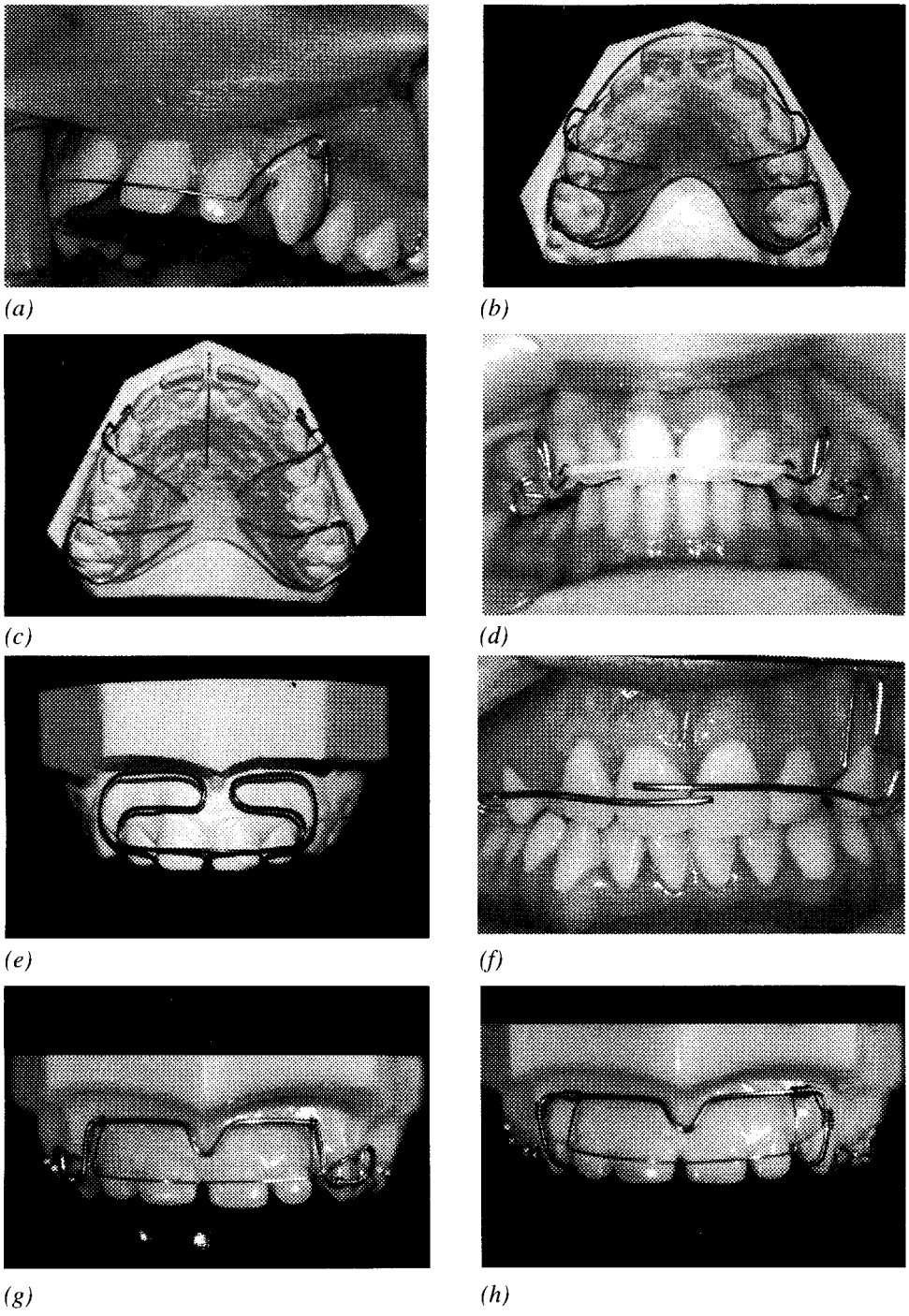


Fig. 8: (a) Roberts retractor with spring sleeved in 0.5mm (I.D.) tubing (b) labial bow retractor (c) elastic hooks with guide to stop slippage of elastic (d) elastic retractor and hooks (e) Mills retractor (f) split labial bow (g) high labial bow with adjustment loops and auxiliary 0.5mm spring (h) high labial bow with auxiliary 0.5mm spring but without adjustment loops.

the midline and activating the arms lingually. This retractor delivers a light force and is easily adjusted. Its elasticity makes it somewhat unstable vertically. The curvature may be varied to suit as the incisors are retracted.

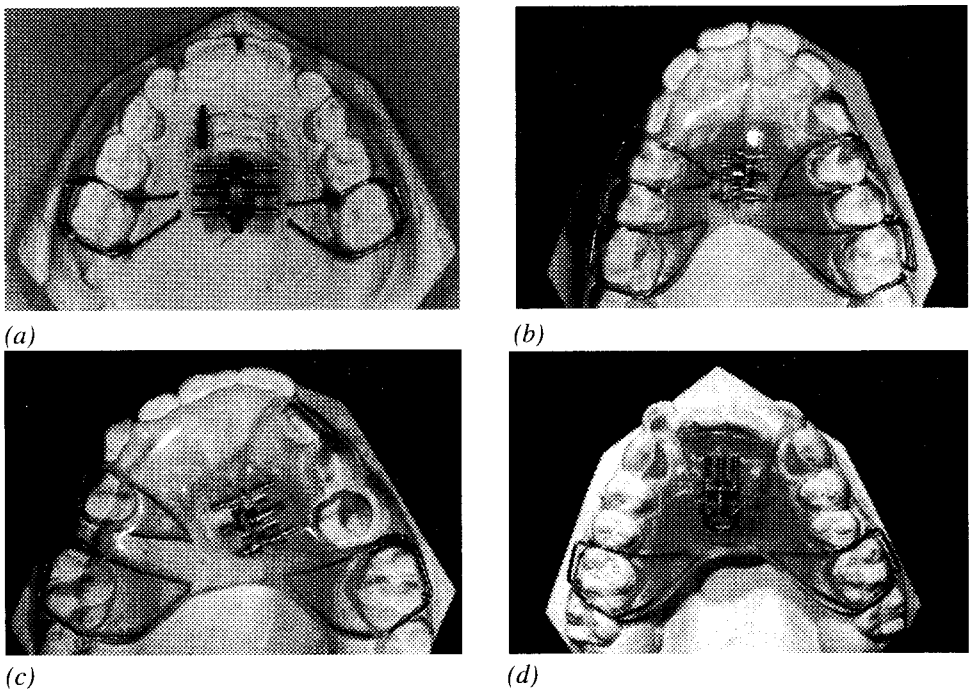
High labial bow – this is used as a frame on to which is wound a light auxiliary spring in 0.5mm wire. The high labial bow is bent from 0.9mm wire and may incorporate adjustment loops.

EXPANSION SCREWS

Single tooth movements or block movement of arch segments may be achieved by expansion screws. A variety of screws is manufactured. The screw is designed to expand in much the same manner as a car jack as the screw is rotated. The screw is opened by the patient on a regular basis, usually one quarter turn twice a week, by inserting a key into one of the holes on the central boss of the screw and rotating the key. Obviously, the screw cannot open unless the acrylic sections attached to the respective ends of the screw are separated by sawing completely through the acrylic to separate both sides. The action of a screw is intermittent, the force being at a maximum immediately after the opening movement. For this reason, unless the patient wears the appliance conscientiously, the screw will open faster than the teeth move and the fit of the appliance will deteriorate. Winding the screw back may help improve the fit before continuing the opening process. For these reasons it is usually better to insist that the patient eat with the appliance in place so that the act of mastication enhances the action of the screw and no relapse can occur at meal times. Removal of the appliance while eating often results in failure to replace the appliance (Fig. 9).

Screws are usually designed to open about 0.25mm for each quarter turn so as not to exceed the width of the periodontal membrane causing compression or necrosis. The slides on each side of the screw stabilise the central screw as it opens. A variation is the single slide to reduce bulk for use in the lower lingual area. To prevent acrylic entering the thread of the screw during processing, a plastic tag is moulded over the central portion. This tag remains in place during appliance construction and is then removed.

While the expansion screw may be used for bilateral expansion to correct a lingual posterior crossbite this application has been largely superseded by the quad helix appliance of Ricketts. The quad helix is cemented to the first permanent molars. Its action is totally predictable and desirable over-expansion is easily obtained. By varying the design of the lingual arms, more expansion can be achieved on one side although most crossbites require bilateral expansion. Removable expansion screw plates are subject to unpredictable cooperation and do not allow rapid movement with over-correction. Another advantage of the quad helix is the ability to achieve some rapid expansion of the maxillary midline suture in younger patients in the mixed dentition.



(a) (b)

(c) (d)

Fig. 9: (a) Expansion screw prior to fabrication of the appliance with protective insert to prevent acrylic flowing into the mechanism of the screw (b) bilateral expansion screw with the acrylic base cut down midline (c) sectional expansion screw with acrylic base cut to move the block of three teeth labially (d) sectional expansion screw with the acrylic base cut to move the two central incisors labially.

Line of action – the screw should be placed in the appliance to ensure that it acts in the correct direction in both the horizontal and vertical planes. The screw should act parallel to the occlusal plane and parallel to the line of the arch nearest to the screw (Fig.10). When used for bucco-lingual arch expansion the screw is placed near the centre of the palate and again should act parallel to the occlusal plane. Where the palatal vault is narrow, it may not be possible to place the screw near the tissues, leading to an undesirably thick layer of acrylic in this region. When being used to expand only one or two teeth, it is also desirable to keep the screw action horizontal but this also may lead to an unacceptably thick layer of acrylic and the screw may have to be canted a little.

Single screws – to move a single anterior tooth labially it is often convenient to use a separate screw applied to the lingual surface of the tooth. Any brass screw of convenient dimensions will be acceptable. These screws may be incorporated in the acrylic or they may be cured into the appliance with self-cured acrylic after fabrication. They are wound out of the acrylic at the rate of one half turn twice a week by the patient. Proprietary single piston screws with spring loaded heads are also available (Fig. 11).

One advantage of screws compared to springs is the ease of insertion of the appliance. When springs are activated they are often very difficult to keep against the sloping palatal tooth surface, tending to slide down incisally. Both screws and springs on

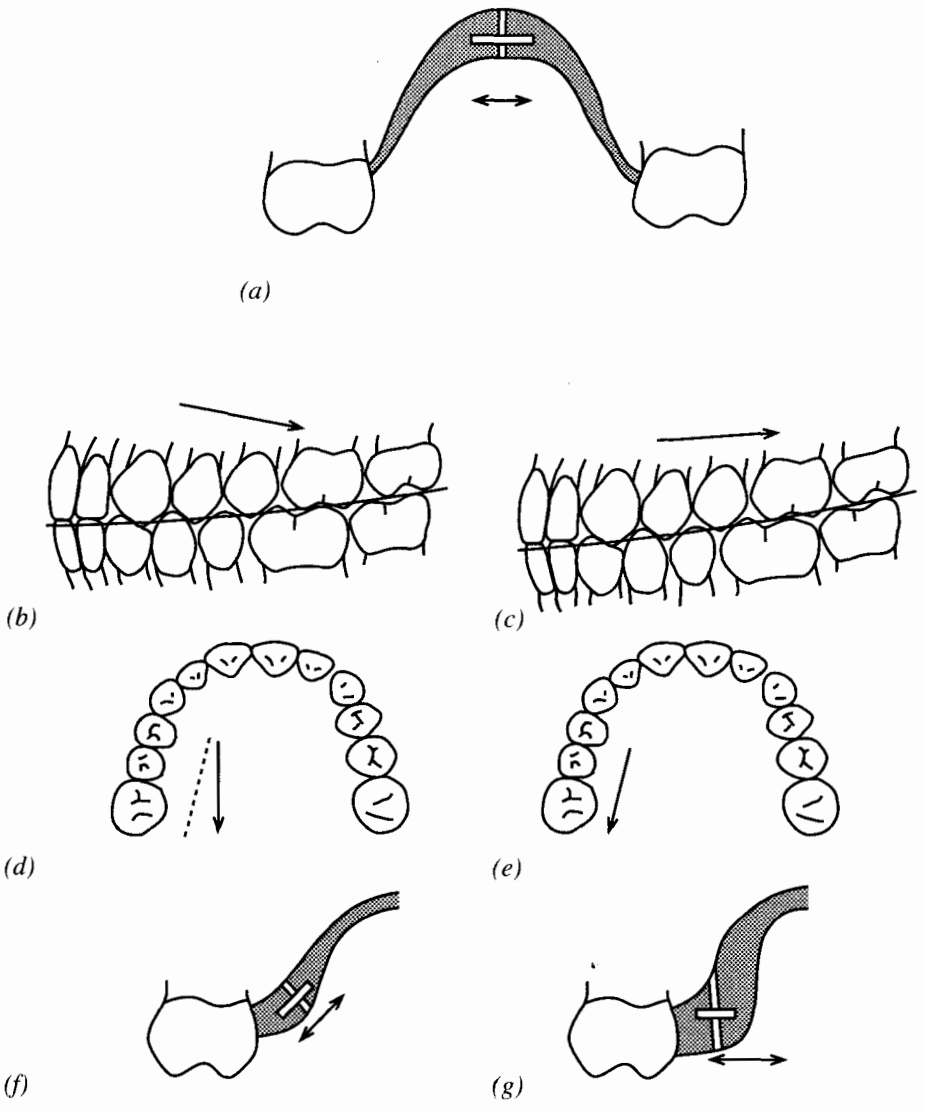


Fig. 10: (a) Correct location of midline expansion screw in the palatal vault (b,d,f) incorrect orientations of the expansion screws (c,e,g) correct orientations of expansion screws.

removable appliances have the disadvantage of tending to depress the incisor as it moves labially. This is because of the slope of the cingulum area and the problem is difficult to overcome. Some elongation of the incisors is often desirable but impossible to obtain with removable appliances of this type.

LABIO—LINGUAL MOVEMENT

A variety of springs is available to move anterior and posterior teeth labially and buccally (Fig. 12). One common design is the cantilever spring which acts parallel to the occlusal plane. It may be difficult to maintain its correct contact position on anterior teeth. It is often difficult for the patient to tuck the spring up between the

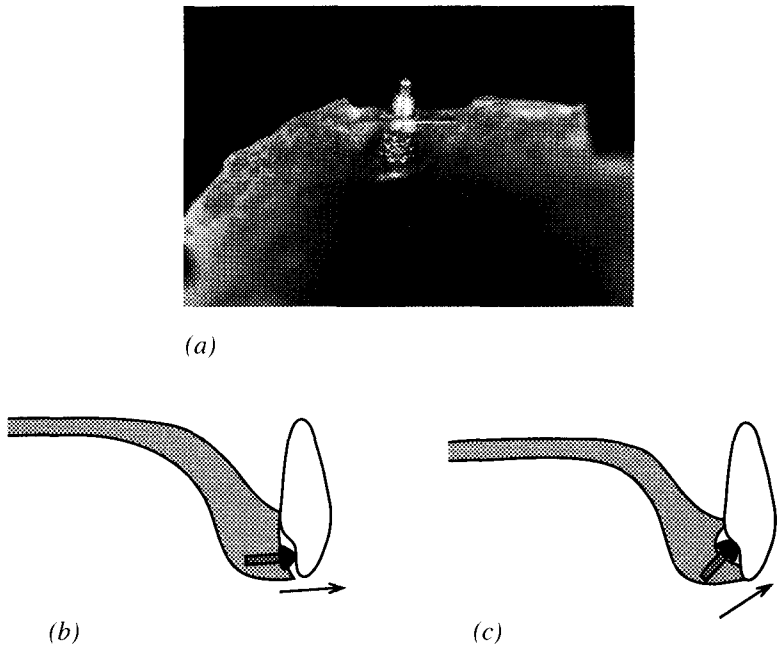


Fig. 11: (a) Spring loaded piston screw for a single tooth (b) correct line of action of screw to minimise depression (c) incorrect line of action which will tend to reduce the overbite with depression and tipping.

acrylic and the tooth after activation. Because these springs are shielded by the acrylic, they are normally constructed from 0.5mm or 0.6mm wire. In order to avoid contact of the arm of the spring with adjacent teeth a crank may be placed in the arm. A variation of the cantilever design, is the double cantilever spring. Activation of both coils simultaneously achieves a straight labial line of action.

Cantilever springs may also be used on posterior teeth but for convenience are often replaced by a simple flapper spring also constructed from 0.6mm wire. Only the very end of both arms is embedded in acrylic. It is activated by simply pulling away from the acrylic base. The passive spring is constructed with the point of contact lying well to the occlusal so that as the tooth moves the spring slides more gingivally. These are very simple and efficient springs. However they do require positive retention or the plate will be displaced from the soft tissues although minimal activation usually avoids this problem.

The lingual movement of individual teeth is often required. Space must be available for the tooth and the lingual acrylic must be trimmed clear of the tooth and attached gingival tissues. Any design variation which is able to give a sufficiently flexible arm in the labio-lingual direction may be used to move individual teeth. The governing factors are the tooth to be moved and the availability of space between opposing teeth where the wire may conveniently cross the line of occlusion.

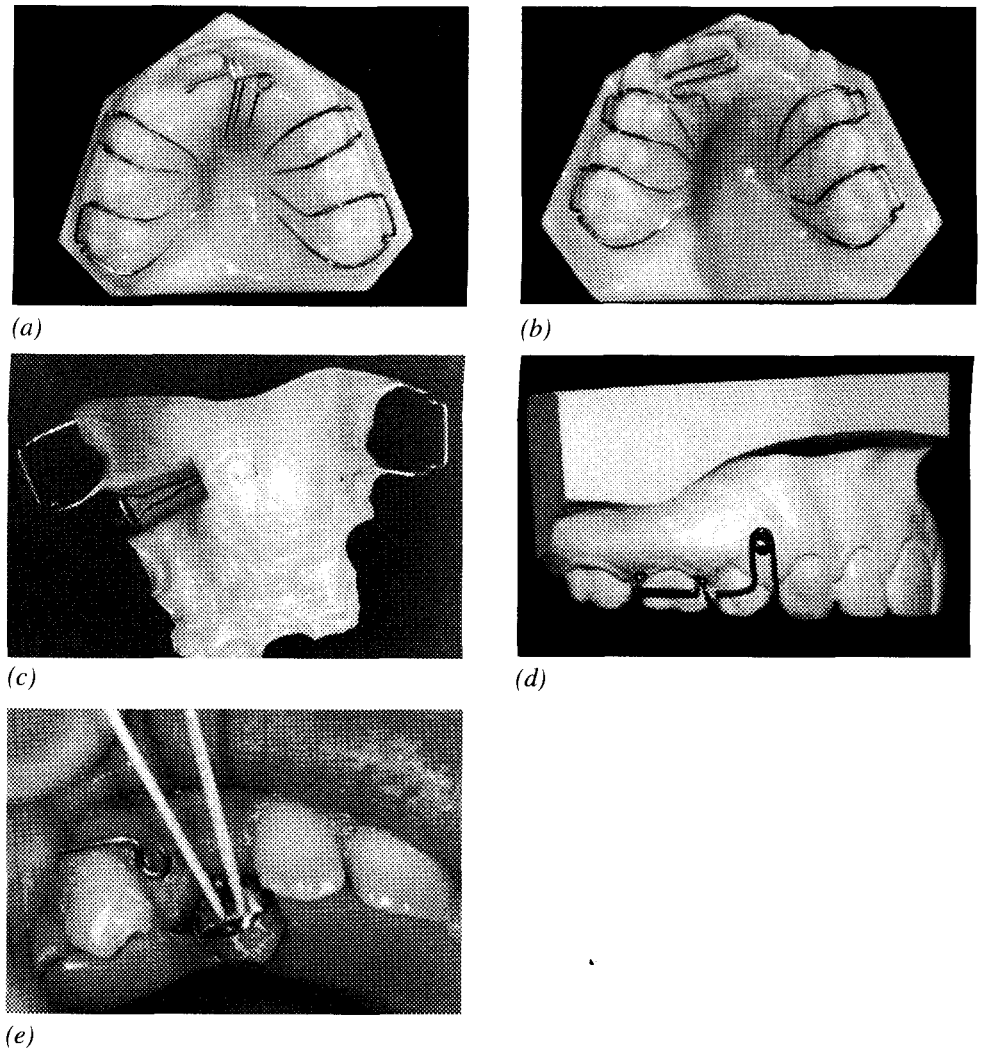


Fig. 12: (a) Single coil cantilever spring with wire stabilising guide (b) double coil cantilever spring (c) flapper spring without coils – note associated 'box' in the acrylic (d) buccal spring to provide lingual force (e) elastic to be connected from the tooth to the traction hook on the appliance.

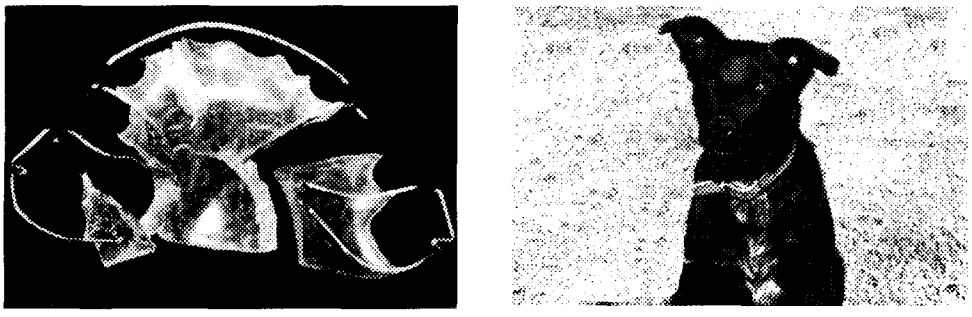
Occasionally it may be convenient to move a lingually placed canine with an elastic from the tooth to a hook on the appliance. A band or bonded attachment is placed on the tooth and the elastic replaced by the patient as required. This device has the potential to provide continuous movement without the need for regular adjustment as required of a spring. This may be important if the patient has to travel long distances.

FITTING A NEW APPLIANCE

The appliance should be fitted soon after the impression and preferably within a week. It is better practice to fit the plate before extractions to ensure it is comfortable

and being worn correctly. Prior to fitting the appliance check that the design is correct and the appliance is finished to an acceptable standard. Incorrect interpretation by a technician does occur from time to time. Place the appliance and check the fit, retention, occlusion and the stability. Look particularly for undue compression of soft tissues. If all is well dismiss the patient for 2-4 weeks before doing extractions or activating the appliance. If extractions are to be done instruct the patient to replace the appliance immediately afterward.

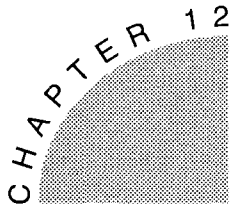
Instructions to the patient in fitting and removing the appliance should be written and explicit with the patient then demonstrating that he or she has acquired the ability to manage at home. Where possible the parent should be present. Standard simple instructions should be supplied with an explanation of any matters which might be unfamiliar. It may be better in many instances for the patient to wear the appliance during meals. Full time wear is far more efficient and bite opening will not proceed well with intermittent wear. Full time wear has a practical advantage in that the appliance is less likely to be lost or broken. Most lost and broken appliances result from placing the appliance in a pocket or on a bench. Many practices supply a special plastic storage container which the patient uses when the appliance is removed. The container bears the name and address in case of loss. Wear during sport or swimming is not advised. Instructions concerning diet should include information on the consumption of sweets or food which might damage the appliance. A seemingly improbable cause of appliance destruction is the family dog and if the appliance is placed within reach it is likely to be gnawed to destruction (Fig. 13).



(a) *(b)*

Fig. 13: (a) A badly distorted appliance (b) the culprit.

During treatment the patient will attend every 4-6 weeks with an active appliance. Passive appliances may be checked every 2-3 months. Patients should be clearly instructed to return immediately in the event of any problem. At each appointment check the fit of the appliance – the most telling indicator of cooperation. If the appliance no longer fits snugly the patient simply is not wearing it enough. Similarly an inability to speak clearly with the appliance in place is an almost certain sign of cooperation problems. Good patients are quickly identified and may be given more latitude. Poor patients are also easily identified but many never seem to improve in spite of encouragement. However, always be sure that the appliance is not the problem.



INTERCEPTIVE ORTHODONTICS

The concept of prevention in orthodontics depends on the underlying etiology of the condition to be treated. It is believed that a large proportion of orthodontic anomalies have a significant underlying genetic component and therefore the potential for true prevention is limited. Brash (1956) concluded that the evidence largely supported genetic factors as the most frequent etiological determinants, modified by environmental factors. Experienced clinicians are frequently astounded by the familial persistence if not inheritance of a broad range of occlusal conditions. Our understanding of genetic regulation is even poorer than our understanding of environmental factors. Contemporary research suggests that the regulation of apparent local anomalies may be associated with quite complex tissue alterations. Most evidence favours a significant genetic overlay in malocclusions associated with severe skeletal anomalies. Varrela and Alanen (1995) have argued that there is substantive evidence to support the contrary view that a large percentage of occlusal conditions are the result of environmental factors and are therefore amenable to interception. They claim that the prevalence of many conditions is a relatively recent development which might be explained by dietary factors, airway problems and sucking habits.

The terms interceptive and preventive orthodontics have been used synonymously. Interceptive orthodontics is preferred because orthodontic anomalies are not truly preventable in the same sense that caries is preventable with a specific strategy such as a low caries diet. This difficulty of definition is further complicated by the unpredictable effects of some etiological factors. For example thumb sucking may cause an anterior open bite or increased overjet in one patient and yet have little effect in another patient. It is largely in those cases where interceptive treatment seeks to influence the muscular environment that uncertainties abound. Interceptive treatment should be applied where benefits will result with a reasonable degree of predictability. This does not mean that the interception must overcome all aspects of the patient's problems at the one time. However, interceptive treatment may alter the natural developmental pattern significantly with no guarantee that the resulting occlusion will be stable. This is particularly true where interception involves early expansion of the dental arches to overcome crowding. The general aim of interceptive treatment is to correct or alleviate identifiable anomalies which interfere with optimal development of the occlusion.

Interception may also be directed at the skeletal abnormalities seen in developing Class II and Class III malocclusions. Some workers believe that skeletal growth modification is possible but the evidence is equivocal. There can be no doubt that remarkable changes in dento-alveolar relationships can be achieved in selected cases

by orthodontic treatment and it might be observed that experienced clinicians have become adept at selecting cases which are most likely to provide a good response. But the capacity of growth modification to permanently alter the genotype is not able to be substantiated. The genotype will partially re-express itself in many cases with eventual relapse of seemingly good results. The discussion in this chapter will be limited to local anomalies.

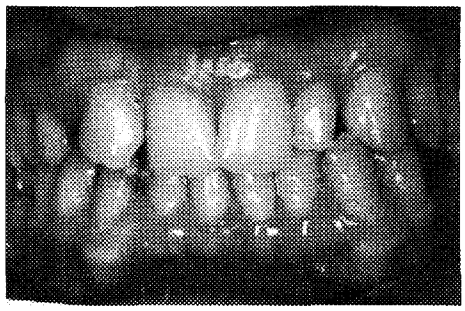
INHERITANCE OF LOCAL DENTAL ANOMALIES

Dental size, morphology and development have been shown to be genetically determined in many instances although most genetic influences are polygenic with the expression of traits being influenced by other modifying genes and environmental factors. Recent evidence suggests that less specific anomalies such as impacted teeth may have a significant genetic background. The mechanism of expression is not understood. Other anomalies which may have a genetic etiology include canine-premolar transposition and deciduous submergence.

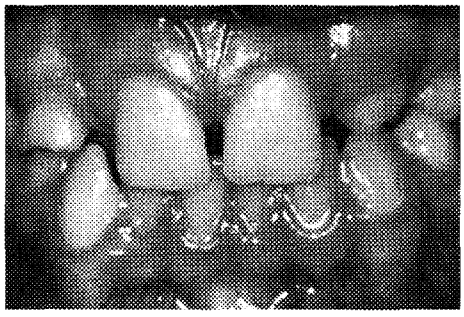
The reported prevalence rates for missing teeth, excluding third molars, vary depending on the population with mandibular incisors being the most frequently missing teeth in Asians whilst in Caucasians it is the maxillary lateral incisor and mandibular and maxillary second premolars. Females are affected more often than males. Of increasing interest is the pattern of association between a range of other dental anomalies and hypodontia. Garn and Lewis (1962) found that where one or more third molars are missing there is a much higher rate of other missing permanent teeth. Keene (1964) noted that when one or more third molars were missing, the remaining teeth in both arches were more spaced and less crowded. A female preponderance, familial occurrence and an association with other dental anomalies including ectopic maxillary canines, maxillary canine-first premolar transposition and other missing teeth, suggest a polygenic etiology (Fig. 1).

Ectopic maxillary canines occur in about two per cent of the population. A female predilection exists and canines are the most frequent ectopically impacted teeth in Caucasians (Peck et al, 1994). Investigation of orthodontic patients demonstrating at least one palatal ectopic canine, showed the lateral incisors adjacent to these canines were missing in a high percentage of cases. Bjerklin et al (1992) investigated 273 children, 93 with infraocclusion of deciduous molars, 91 with ectopic eruption of maxillary canines, 97 with missing premolars and 92 with ectopic eruption of maxillary first permanent molars. Ectopic eruption of maxillary canines occurred with a higher frequency than normal in children with any of the other three dental anomalies.

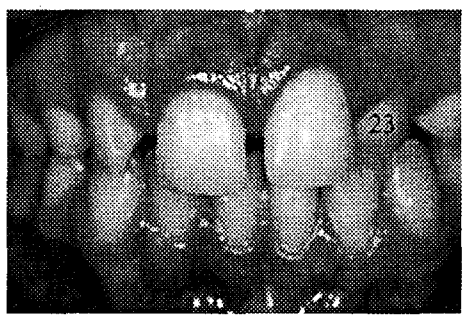
Repeated patterns of tooth malposition, malformation and hypodontia (excluding third molars), occur simultaneously in family members in proportions that clearly exceed the proportion of these anomalies occurring in the general population. It has been concluded that palatally ectopic canines are an inherited trait, being one of the



(a)



(b)



(c)

Fig. 1: (a) Missing permanent lateral incisor in mother's dentition (b,c) missing lateral incisors in the dentitions of her two daughters.

anomalies in a complex of genetically related dental disturbances, often occurring in combination with missing teeth, tooth size reduction, supernumerary teeth and other ectopically positioned teeth (Kotsomitis et al, 1996).

Maxillary canine-first premolar transposition is a positional interchange of these two teeth (Fig. 2). It is a relatively rare phenomenon with a reported prevalence of about 0.25 per cent in the general population but a study of 43 orthodontic patients (Peck et al, 1993) with maxillary canine-first premolar transpositions, revealed one or more missing teeth (excluding third molars) in 37 per cent of cases. The most frequently missing teeth were the maxillary lateral incisors and mandibular second premolars. Peg-shaped maxillary lateral incisors occurred in 16 per cent of cases. In total, 49 per cent of individuals had other dental anomalies.

The reported prevalence of deciduous molar submergence varies widely although previous studies suggest that about 9 per cent of deciduous dentitions might be expected to show the trait, with mandibular first and second molars most often affected (Kurol, 1981, 1984) and the siblings of affected children are likely to be similarly affected in about 18 per cent of cases. In monozygous twins, nearly identical patterns and degrees of submergence are likely to be found. The association between deciduous submergence and permanent absence of the associated permanent tooth is well known. These findings along with the fact that a variety of dental anomalies

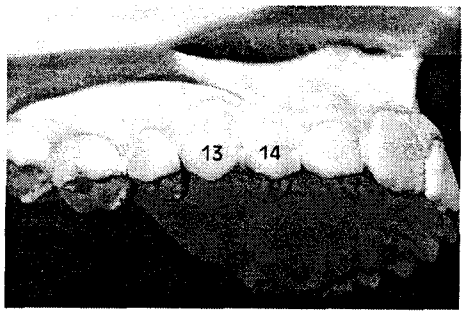


Fig. 2: Transposition of the upper right canine which was accepted.

are associated with other missing teeth and maxillary canine-first premolar transposition, implies a significant genetic component in the etiology.

ECTOPIC CANINES

The importance of being aware of significant etiological factors and of constantly assessing the positions of developing canines has been stressed. Another indication may be excessive distal angulation of the crown of the lateral incisor. The discovery of a palatally impacted canine in the young adult patient can be a particularly distressing episode when nearing the end of secondary school. Treatment time is always protracted and fixed appliances are almost always required. Most of these problems can be successfully intercepted if detected early enough. Always suspect the developing canine and take nothing for granted. In the upper arch deciduous extractions and space maintenance will often be sufficient. While seen less frequently, lower canine impactions may occur. These may be particularly difficult to recover. Examination of the OPG nearly always shows tell-tale signs of problems. It is surprising how quickly the problem may deteriorate from a preventable situation to full impaction (Fig. 3).

Where the tooth is already in an ectopic position, surgical exposure and traction will be required to move the tooth into the correct position. A variety of technics are recommended by different clinicians. Some prefer to expose the tooth, place an attachment and then re-suture the wound, drawing the tooth through the mucoperiosteum. Others prefer to expose the tooth widely and to pack the surgical site to encourage epithelialisation with direct access to the crown after the pack is removed. At this time the attachment is bonded to the tooth. The latter method has the distinct advantage of being fail-safe with very little chance of requiring further surgical exposure of the tooth. Less frequently the canine seemingly becomes impacted on the labial aspect with very little eruption progress. Exposure and limited channelisation of the cortical bone will usually be enough to encourage eruption. An experienced oral surgeon will often be better able to assess the extent of surgical intervention at the time of operation.

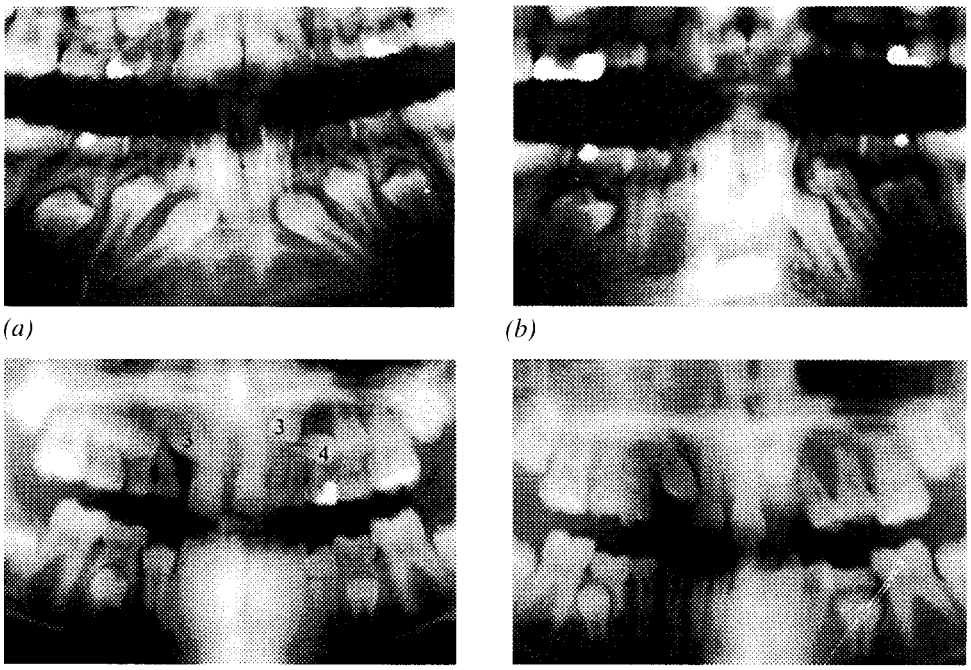


Fig. 3: (a) Lower canines showing early signs of abnormal angulation without interceptive action (b) approximately 18 months later showing one canine totally impacted (c) upper canines showing abnormal angulation positions and one first bicuspid distally impacted (d) approximately 18 months after preventive extraction of upper deciduous teeth and space maintenance.

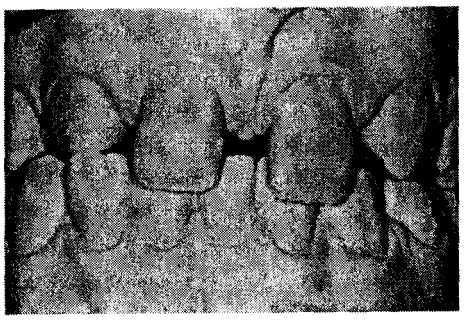
MAXILLARY DIASTEMA

The maxillary median diastema may be a disfiguring trait when wider than 1mm or so (Fig. 4). While of little importance in terms of dental health, the condition is not esthetically acceptable to many people.

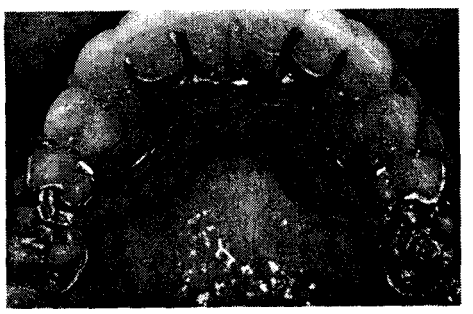
The causes of a diastema include:

- Heredity
- Development associated with eruption of incisors and canines – ugly duckling stage
- Small permanent teeth and small or missing lateral incisors
- Obstruction due to fleshy frenal insertion
- Obstruction due to a supernumerary
- Proclination of the upper incisors
- Rarer pathological conditions such as cysts.

The treatment of the problem will vary with the cause. There is rarely any need to do much until the lateral incisors are completely erupted. If the lateral incisors are



(a)



(b)



(c)

Fig. 4: (a) Large disfiguring diastema due to missing lateral incisors (b,c) restored by closing the space and replacing the lateral incisors on a cast partial denture.

congenitally absent the central incisors may be moved together with replacement of the lateral incisors. When the diastema is wider than 1 mm or so closure of the central incisors causes considerable compression of the midline gingiva and in some instances it will become inflamed due to compression. For these reasons frenectomy after closure of the space is recommended in a high percentage of cases perhaps followed by bonded lingual retention. Where any obstructive object such as a supernumerary is present, this must be removed prior to space closure. Some workers have also advocated the frenectomy prior to closure although it is most often done after closure.

Where there is a pronounced low inter-dental attachment of the frenum it may actually penetrate into a suture visible on x-ray between the central incisors. In these cases, the fibrous tissue of insertion must be removed between the incisors. This can be a very delicate operation with a likelihood of root damage and frenectomy prior to tooth movement may be desirable. In addition, the soft tissue removal must be done with care so that a gingival dehiscence does not result, leaving a triangular space between the teeth. Even in the mixed dentition stage where there is a large space between the incisors which is not developmental, interception and early space closure with retention may be desirable. With the availability of bonded brackets this is a simple exercise. In all cases, surgery should be conservative.

SUBMERGENCE

The condition is due to ankylosis of the tooth to the surrounding bone, obliterating the periodontal membrane at one or more points and stopping the tooth from erupting in concert with growth in height of the surrounding bone. When submergence is seen the absence of the permanent successor should always be suspected. The association is much stronger in females than males. Estimates of the prevalence of submergence vary from about 2 to 10 percent. The order of decreasing prevalence is lower second molar, upper second molar, lower first molar, upper first molar. Submergence may appear as early as four years of age. With increasing age both the prevalence and severity increase. Many causes have been suggested including trauma, reduced occlusal function, heredity and localised abnormality of bone metabolism. More than one child in the same family is likely to be affected.

The life cycle of a deciduous tooth prior to exfoliation is normally associated with root resorption and bone deposition. With the submerged or ankylosed tooth, bony union occurs in the resorption lacunae in the dentine of the root. In other areas, continuing resorption may be occurring at the same time. A few of these teeth will remain ankylosed and will continue to submerge to the point of complete coverage by the surrounding tissues. This seems to be more likely with second deciduous molars. Most eventually exfoliate naturally with eruption of the premolar (Fig. 5).



Fig. 5: Ankylosis with submergence of the upper left and lower left second deciduous molars. Note the forward tipping of the first permanent molars.

Treatment of the condition ought to be varied to suit the particular conditions of the patient including the severity of submergence, age, particular tooth and health of the patient. There is rarely any immediate need for interception. Observation, along with study models, may be all that is required. With increasing age, the condition may become more pronounced and if the first molar beings to erupt over the submerging tooth, interception should be considered (Fig. 6). In the absence of any immediate problems which dictate intervention the tooth should be given every chance to exfoliate naturally. The notion that submerged teeth should be extracted immediately is not warranted.

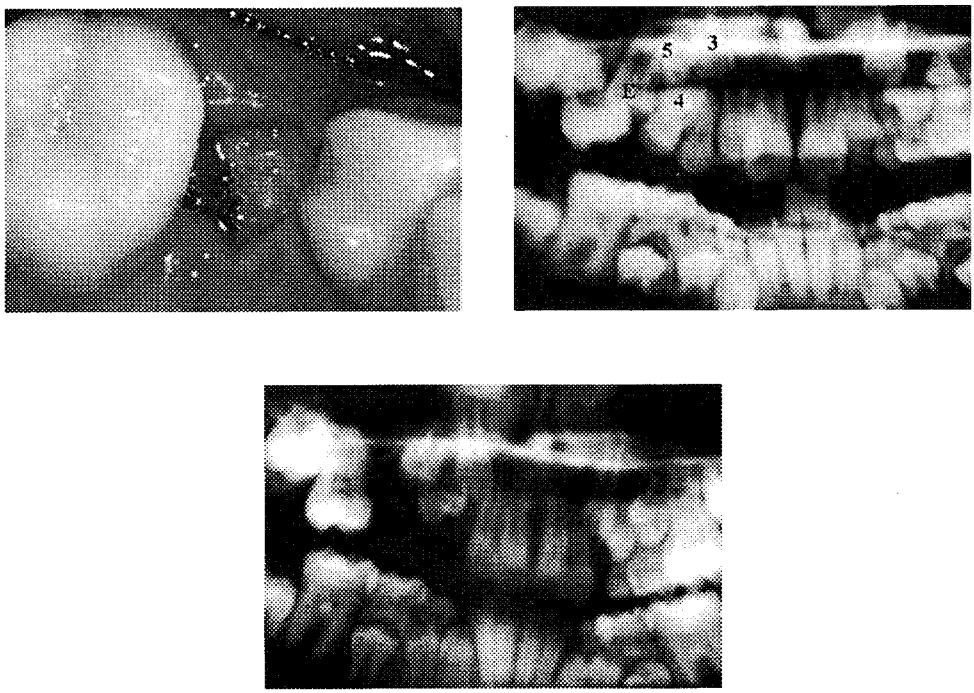


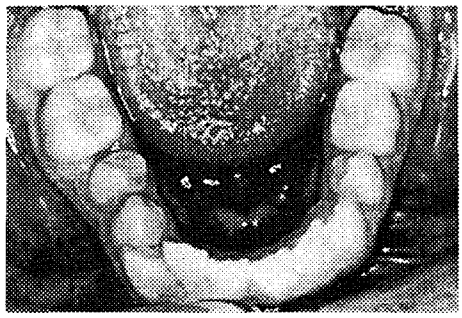
Fig. 6: Series showing clinical appearance of an almost totally submerged upper left second deciduous molar and radiographic appearance of the same area with very high displacement of the second bicuspid. After removal of the second deciduous molar and space maintenance there was natural improvement of the positions of the permanent teeth.

CONGENITAL ABSENCE

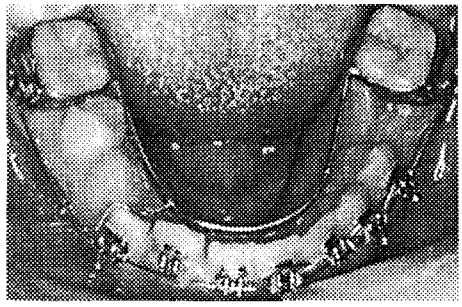
The congenital absence of permanent teeth should be checked radiographically at least once in the middle mixed dentition phase of each child. The most commonly absent teeth, in decreasing frequency, are third molars, maxillary lateral incisors and mandibular second premolars. Garn and Lewis (1970) have shown that missing teeth and reduced size of the remaining teeth commonly occur in the same patient, the missing tooth being an extreme example of tooth size reduction. This can cause considerable trouble in treatment because it often means that space closure for the missing tooth will be made even more difficult because of the small remaining teeth. Prosthetic replacement of the missing tooth may give a better long-term result, but must be balanced against other considerations such as cost, oral hygiene and personal preferences of the patient and parent.

For these reasons, early detection of congenitally absent teeth may be most useful in determining the treatment plan. In the case of missing lower second bicuspids very early extraction of the deciduous precursor may be indicated along with observation of the first permanent molar. Difficulty may arise where the absence occurs on one side only and centre line shift to the same side may be considerable. Consideration may be given to extraction on both sides if extraction of a bicuspid

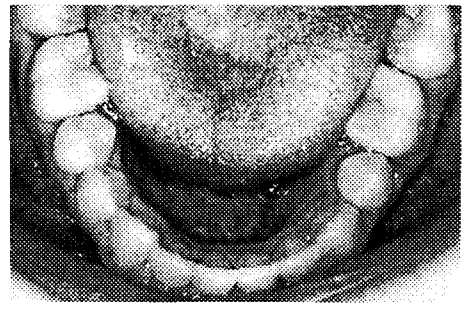
on the non-missing side will be required later. Much depends on the general dento-facial morphology of the case and the desirability of extractions. With careful stabilising biomechanics, unilateral space closure on the missing side only may be advisable in some circumstances (Fig. 7).



(a)



(b)



(c)

Fig. 7: (a) Congenitally absent lower left second bicuspid (b) stabilising mechanics to close space unilaterally and preserve other bicuspids (c) space closure at bands off.

These dilemmas highlight the difficulty of clinical management in young children where the intentions of interceptive treatment may be laudable but the consequences are often not as controllable as might be imagined. For example in a child with indifferent oral hygiene and a doubtful dental attendance pattern, the best course of action may be to do nothing. In some cases with missing permanent second bicuspids the deciduous second molars may last for many years well into adulthood. Sensible assessment suggests that in the absence of any signs of root resorption or submergence, the situation might be left alone in many cases. A balanced approach to the problem of missing permanent teeth may be very difficult to achieve. Certainly there is no cookbook solution available for any case. An orthodontic assessment will often help the general practitioner to reach a decision.

The congenital absence of other teeth, such as lower incisors or upper canines, occurs less frequently. The absence of a lower incisor is very easily missed unless the examiner actually makes a count of these teeth at examination. Missing permanent canines may also be easily missed. Missing upper lateral incisors offer a particular diagnostic challenge because the decision often must be made early to either close

or open the space. Both options have advantages and disadvantages (Fig. 8). Where the permanent canine has erupted mesially to the deciduous canine against the central incisor, the appearance may be reasonably good. If the deciduous canine is firm and unresorbed, many patients will take the option to leave the situation alone. Often the deciduous canine will show signs of resorption and its longterm prognosis becomes a factor in treatment planning. Even so, many parents and patients find it difficult to accept that the deciduous canine should be extracted and the space closed from behind or the permanent canine retracted to open the lateral incisor space which then has to be restored.

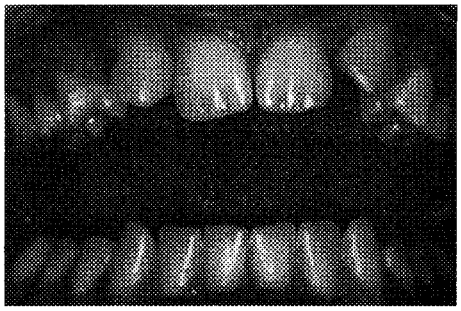


Fig. 8: Missing upper lateral incisors without significant residual space.

A further difficulty arises where there is evidence that the permanent canine is erupting palatally. Congenital absence of the lateral incisor has been shown to be highly correlated with the palatal eruption of the permanent canine. Ericson and Kurol (1988) have shown that interceptive extraction of the deciduous canine will often correct the ectopic position of the permanent canine if performed early enough to allow the permanent tooth to drop down and back within the alveolus. If such an extraction is warranted, this will then create the need to make a decision for the longterm management of the missing lateral incisor. While space closure seems to be the most appealing option in many cases, it may be an extremely demanding and lengthy process requiring full upper and lower fixed appliances for the purposes of elastic traction. Even then, space closure may be incomplete if the general size of the teeth is below average as suggested by previous research. Space opening and replacement is certainly easier and quicker in the presence of large spaces and the appearance may be much better, particularly where the canines are very pointed or conical. The patient's oral hygiene will be an important determinant of the objectives. Experience suggests that treatment planning for this problem and consultation with the referring dentist, parents and patient may be a very protracted process with people changing their mind several times in some cases, particularly where the parents and the patient disagree between themselves.

SUPERNUMERARY SUPPLEMENTAL AND ANOMALOUS TEETH

Excluding odontomes, extra teeth may be of two basic types - teeth of good shape (supplemental) or teeth of abnormal shape (supernumerary). Although the distinction is artificial, the presence of a supplemental tooth may offer more treatment options (including no treatment) than a supernumerary tooth. The most common supplemental teeth are upper and lower lateral incisors. Supernumerary teeth classically occur as mesiodens between the upper central incisors and may cause non-eruption of the incisor or a diastema (Fig. 9). Removal of the supernumerary is suggested before closure of the diastema. The need for surgical removal of any supernumerary must always be balanced against the possible benefits. On occasions, the best treatment may be no treatment particularly where the supernumerary is deeply embedded and not causing any problems. If the supernumerary is preventing eruption of another tooth, early removal is usually required with minimal bone removal by the surgeon. A space maintainer may also be required.

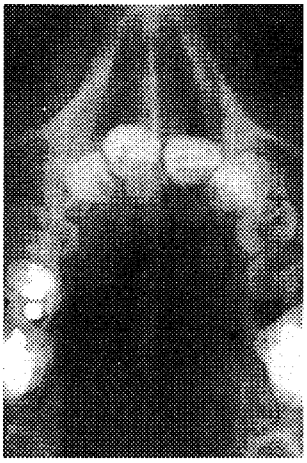


Fig. 9: Mesiodens lying palatal to the upper central incisors and associated with a small diastema.

The management of supplemental teeth is governed by the general appearance and arrangement of the dentition. An extra lower incisor is not uncommon and may cause no problems at all. An extra upper incisor may be more obtrusive but even here the patient must be the ultimate arbiter of the management of the tooth. Don't make problems where none exists. The benefits of intervention must be predictable. In the presence of an overlying malocclusion where other extractions are warranted, the management of the extra tooth must be integrated in the overall plan.

Teeth of anomalous shape occur due to twinning, gemination, microdontia and macrodontia. Where the appearance is unacceptable to the patient, all the options must be considered including reshaping. Masking with adhesive restorative material

may be beneficial. In some instances the patient may be happy to accept the condition. In the absence of an associated malocclusion there is rarely any need for immediate action.

IMPACTED FIRST PERMANENT MOLARS

Impaction of the first permanent molar under the distal aspect of the second deciduous molar is often but not always a sign of future crowding in the permanent dentition. Many methods have been designed to disimpact the tooth including a separating wire or elastic placed around the contact between the first permanent molar and the second deciduous molar. Proprietary springs are also available which exert a gradual pressure forcing the permanent tooth distally far enough to disimpact it. Experience suggests that none of these devices can be guaranteed to be successful. Extraction of the deciduous tooth and placement of a removal appliance with a wire loop against the mesial surface of the unerupted tooth may be an option if more conservative options fail. This then commits the patient to a space management program until the bicuspids erupt.

However, care must be taken to ensure that the decision to extract the deciduous tooth is made in the context of an overall longterm space management plan. Is it likely that there will ultimately be a need for extraction of four bicuspids? Does the dentofacial morphology suggest that permanent extractions are contraindicated? Might extractions be done in the upper arch only? Failure to hold the first permanent molar will result in its forward migration with complete space loss and perhaps centre line shift to the same side if the patient is in the early mixed dentition stage. The developing second bicuspid will become completely blocked out. In the absence of any treatment the second bicuspid will often erupt onto the palate. If the molar impaction is minor and there are no symptoms, it may be better to simply accept the anomaly with periodic observation.

BICUSPID ANOMALIES

From time to time retained deciduous teeth may cause displacement of the erupting permanent successor. This may be seen in the incisor, canine and second premolar regions. The retention of the deciduous tooth may cause the permanent tooth to be guided away from the normal eruption path either lingually or buccally (Fig. 10). In most cases the deciduous tooth will be exfoliated and the permanent tooth will eventually make its way into place. However a timely deciduous extraction may help to guide the permanent tooth into the correct position more quickly. Occasionally the permanent tooth may become displaced into a crossbite position either lingually or buccally all for the sake of early extraction of the deciduous predecessor. This is particularly true in the upper second bicuspid region. A retained deciduous tooth may be an important pointer to other difficulties (Fig. 11). It bears repeating that positional anomalies of one tooth are frequently accompanied by anomalies of other teeth and careful radiographic examination is required.

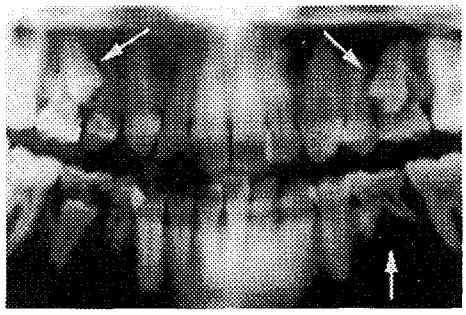
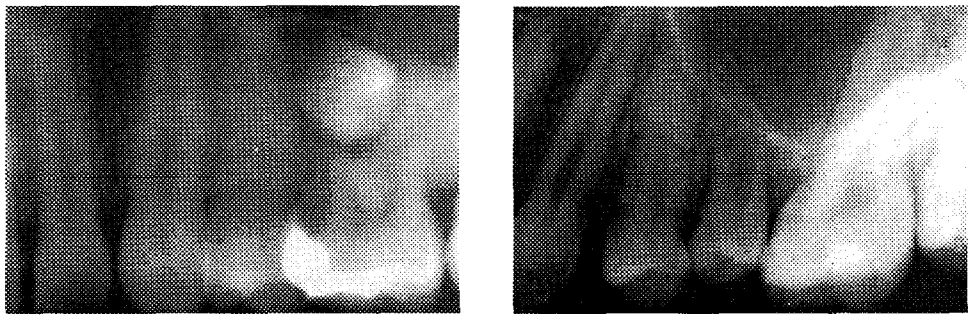


Fig. 10: Joint occurrence of missing lower second bicuspid and badly displaced upper second bicuspids.



(a) *(b)*

Fig. 11: (a) Retained upper second deciduous molar and significantly delayed formation of the second bicuspid. No immediate treatment was undertaken (b) eruption of the second bicuspid about four years later.

LATE DECIDUOUS EXFOLIATION

Delayed deciduous exfoliation is encountered relatively frequently and exhibits a strong familial tendency in many cases. The dentist is often confronted with the decision whether or not to delay treatment because of late eruption of the permanent teeth. Usually the parent will volunteer the information that the child was late in erupting the deciduous dentition and in the various stages of dental development. There is frequently a similar history in siblings or even parents. Delayed deciduous exfoliation may delay the completion of treatment or result in the need for two stages of treatment. In the presence of a substantial skeletal problem, much can be achieved by an early stage of treatment irrespective of the state of eruption of the canines and bicuspids. However, occasionally treatment drags on waiting for the eruption of permanent teeth and patients become very unhappy.

DIGIT SUCKING

Digit sucking is a relatively common practice which causes few problems when discontinued at about 2-3 years of age. However, prolonged thumb or finger sucking may cause significant deformation of the dental arches leading variously to openbite, crossbite, proclination of the upper incisors and retroclination of the lower incisors. Some children may show a callus on the thumb or finger caused by the constant irritation of the edges of the teeth. Pronounced persistent digit sucking may cause distortion of the alveolar area, and narrowing of the dental arch when associated with an abnormal swallowing pattern. The mandible and tongue are lowered to accommodate the digit. Sucking leads to an imbalance of forces between the buccal musculature and the tongue with constriction of the upper arch. There may be an associated overeruption of the posterior teeth contributing further to the anterior open bite caused by the digit. The particular combination of effects seen in the individual will depend on the persistence of the habit and the underlying dento-skeletal relationships (Fig. 12).

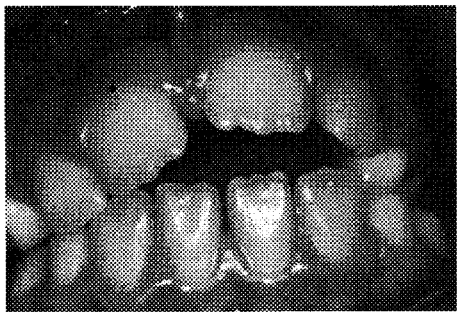


Fig. 12: Finger sucking habit with anterior open bite and contraction of the upper arch. Note also the heavy and inferiorly attached frenum.

Active digit sucking may occasionally be an indicator of personal issues and should be circumspectly investigated. In some instances the habit provides personal gratification and the child seems perfectly happy. Often parents become upset by the habit with constant nagging of the child. While the good intentions of interceptive treatment may be apparent to the clinician and the parent, some children will not cooperate with treatment. The sensory satisfaction derived from digit sucking may be considerable. Rarely, a child may be prepared initially to wear a preventive appliance only to request its removal after a time even with helpful parental encouragement. Only when the child is convinced of the need to desist will interceptive or definitive treatment be successful in many cases. Regular positive encouragement by the parent without nagging is strongly recommended.

Where damage to the occlusion is apparent and the child will not react strongly against treatment, some form of interceptive treatment should be undertaken to break the habit. However, it should be emphasised that even with fixed appliances, treatment will often fail unless the child has reached a stage of wanting to stop the

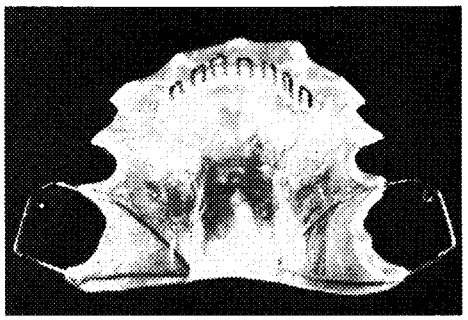


Fig. 13: Removable appliance with a tongue crib.

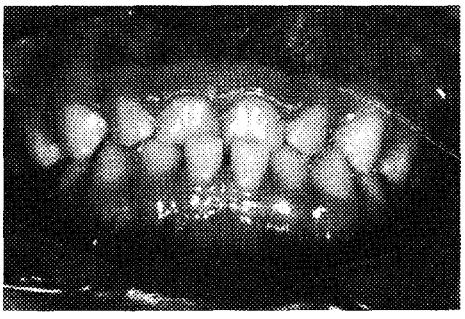
practice. This usually occurs after 7-8 years when the child is more capable of reasoning and peer pressure becomes more direct. Threats or inducements are not likely to gain the child's confidence. Continued thumbsucking into the teenage years is seen infrequently and the clinician must be careful not to belittle the patient in any way, particularly in front of the parents.

Preventive appliances appear to be cumbersome, but they are usually worn with relatively little complaint. A common design incorporates some form of finger guard or tongue crib which makes it difficult for the child to achieve a sucking seal and helps prevent forward thrusting of the tongue. Removable appliances may be successful on occasions but they tend to be unconsciously discarded at night (Fig. 13). For this reason a fixed palatal appliance is more likely to be successful. In cases where a crossbite already exists the fixed appliance may be designed to achieve lateral expansion at the same time.

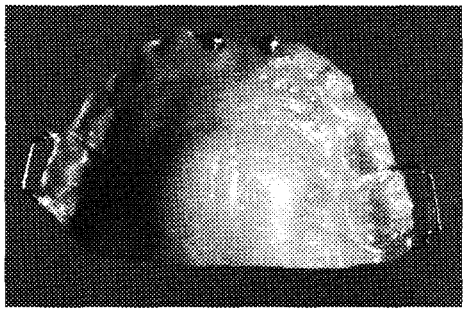
CROSSBITE

Crossbite may be a localised problem or it may occur as one feature of a more extensive anomaly as in Class III malocclusion. It may occur in either the buccal or anterior region. The principles of treatment of buccal or anterior crossbite are broadly the same. Where the underlying skeletal pattern is within normal limits the crossbite should be corrected early in order to place the teeth in a position to promote optimum development of the surrounding bony alveolar structures.

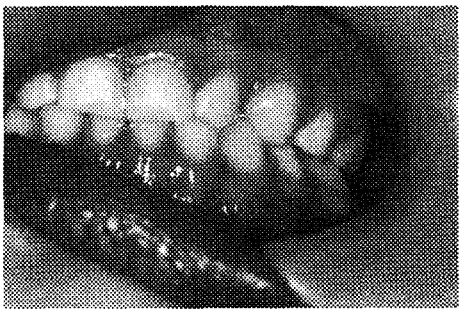
Anterior crossbite is a relatively common abnormality and may be detected in the deciduous dentition. When associated with a mandibular displacement on closure, early correction is aimed toward correction of the centric occlusion - centric relation (CO-CR) discrepancy as much as the correction of the crossbite itself. Treatment should be undertaken as soon as conveniently possible even in the deciduous dentition if the child is able to cooperate well. A removable appliance with screws or springs may be sufficient to accomplish the initial phases of treatment in the deciduous or mixed dentition although cooperation and parental supervision are important for success (Fig. 14).



(a)



(b)



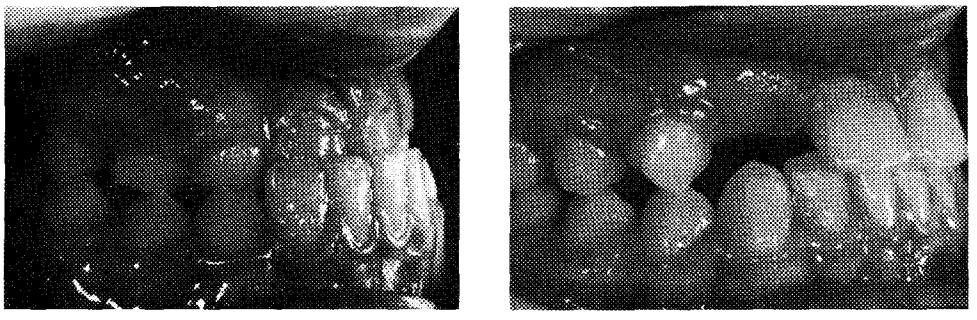
(c)

Fig. 14: (a) Anterior deciduous crossbite (b) simple appliance with brass screws used to correct the position of the deciduous central incisors – note the posterior bite plate (c) corrected incisors showing wear facets on the labial surfaces.

Many anterior crossbites, even in the deciduous or mixed dentitions, are indicative of a Class III skeletal problem. Anterior displacement of the mandible and the associated crossbite may also occur in Class I skeletal cases. These have been termed pseudo Class III malocclusions. In reality true pseudo Class III malocclusions are rare. There is frequently an element of prognathic skeletal abnormality present as the initiating factor causing an incisal edge-to-edge contact which then causes a slide forward into anterior crossbite (Fig. 15).

One limiting factor in the simple correction of anterior crossbites is the amount of overbite. In true skeletal Class III cases, anterior overbite may be minimal so that the corrected incisor relationship has no natural retention. Labial tipping of an incisor may cause further overbite reduction as the tooth swings out and up particularly where the appliance is removable and is unable to control the vertical position of the tooth being moved. Early correction of a central incisor crossbite may be followed by lingual eruption of the lateral incisors which also need correction. However, the need for ongoing treatment is a feature of interceptive treatment in the true Class III case.

Lingual crossbite may occur as a result of functional narrowing of the upper arch in a Class II division 1 case with digit sucking. It may also occur in a Class III case with an inherently small maxilla. An important factor is the angulation of the teeth in the buccal segments. Where the teeth are lingually inclined, simple expansion



(a) (b)

Fig. 15: (a) Anterior crossbite with forward mandibular displacement (b) after correction with a simple removable appliance to procline the upper central incisors.

with labial tipping may be all that is required and can be achieved with a variety of appliances including a removable expansion appliance. Where cooperation is in doubt, more predictable results will be achieved with a quad helix appliance. It has the further advantage of allowing differential anterior and posterior expansion by more or less anterior or posterior activation. The helixes or coils in the appliance provide a very flexible and fast acting expansion mechanism. In the younger patient, the quad-helix will cause some palatal splitting as well as tooth movement through the bone .

As the skeletal pattern becomes more Class III the effectiveness of arch expansion and crossbite correction diminishes. Some temporary relief of severe malpositions of individual teeth may be achieved with deciduous extractions followed by permanent extractions where a thorough case analysis indicates that permanent extractions are indicated. The best longterm treatment may be orthognathic surgery. However, in a child of nine years of age the prospect of living with a severe anterior malalignment for five or six years is not very inviting. Nevertheless excessively prolonged active orthodontic treatment programs are rarely well tolerated and the clinician must often tread a difficult path between trying to alleviate the immediate problems while not overburdening the patient too early where surgical treatment is likely to be required after the cessation of growth.

When the teeth are already buccally inclined and in lingual crossbite, simple buccal tipping is less desirable. In these cases, rapid palatal expansion with as little tipping as possible is more desirable (Fig. 16). This is achieved with a rigid fixed appliance and screw cemented directly to the teeth in order to minimise tipping as the teeth move laterally. A variety of appliance designs have been proposed (Spolyar, 1984). The aim of the appliance is to cause dysjunction of the midpalatal suture allowing relatively rapid basal expansion of the two maxillae. Sometimes surgical augmentation is justified in the older patient where suture dysjunction may not be predictable.

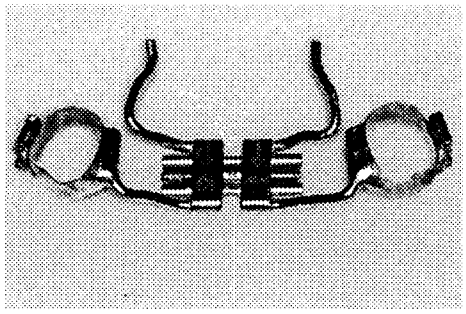


Fig. 16: Fixed upper expansion device for rapid maxillary expansion of the midpalatal suture.

SCISSOR BITE (BUCCAL CROSSBITE)

Scissor bite refers to the complete buccal position of the upper teeth. It is sometimes associated with a narrow lower arch, combined with excessive width of the upper arch. Scissor bite on individual teeth such as the first bicuspids is a common phenomenon. It is also common in Class II division 2 malocclusions, particularly in the upper first bicuspid regions. Class II division 2 malocclusions tend to have a broad square upper arch which places the upper first bicuspids outside the lower first bicuspids. Early detection and treatment of this problem is desirable for long-term stability. The aim is to coordinate the upper and lower arch widths for optimal development. Treatment can be very testing as lateral expansion of the lower arch is not easy. Fixed appliances are often required to achieve an acceptable result. Cross-elastics are sometimes required to achieve reciprocal movement of upper and lower teeth. Expansion of the lower arch may be helped by a lingual bi-helix expansion arch. Early treatment of this condition helps to ensure normal occlusal development and stability.

EARLY DECIDUOUS LOSS

The philosophy of treatment of early deciduous loss is one of the most vexatious issues in interceptive orthodontics. Suggested managements range widely from careful space preservation to no treatment. A set of study models and close observation are a good starting point in all cases of doubt. Ronnerman (1965) suggested that the following principles should govern management :

1. The earlier the deciduous loss the more likely is space closure.

2. Loss of the second deciduous molar is much more likely to cause significant space loss than is loss of the first deciduous molar.

3. Loss of the second deciduous molar before eruption of the first permanent molar may lead to substantial space loss.

4. Loss of either first or second deciduous molars after 9 years is less likely to cause significant space loss or longterm problems if the permanent teeth are well developed.

5. Loss of deciduous canines is likely to be the result of crowding rather than the cause of crowding and unilateral loss will cause centre line shift.

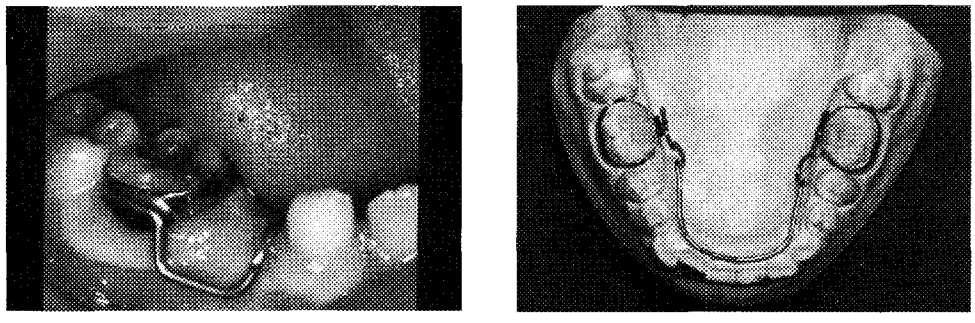
Early loss of the second deciduous molar is most likely to result in significant space loss. Loss of the second or first deciduous molar may result in shift of the centre line to the same side. Pulp therapy of deciduous teeth may be a beneficial temporary measure in cases of very early loss of second deciduous molars. Unilateral loss of a deciduous canine should at least be treated by extraction of the same tooth on the other side to prevent centre line shift. If space maintenance is necessary it will usually be required over an extended period. Removable appliances are not recommended in many instances. Serious space maintenance generally requires a fixed lingual or palatal arch of at least 0.9mm wire soldered to bands on the first permanent molars (Fig. 17).

Given the assumption that adequate study models, xrays and other records will be acquired, the general rules of space maintenance are:

1. Where possible, hold the deciduous molar as long as possible using pulp therapy if necessary. This applies particularly to the second deciduous molars which are key space holders.

2. Early loss of the second deciduous molar before about 9 years or before half root formation of the second bicuspid, should be treated with a lingual arch if there is any sign of space loss which will interfere with eruption of the bicuspids and will not allow maximum use of the leeway space in minimally crowded cases.

3. Early loss of first deciduous molars may not require space maintenance if the second deciduous molars are still present. The most important aspect of first deciduous molar loss is centre line shift of the incisors if the extraction is unilateral.



(a) (b)

Fig. 17: (a) Fixed local space maintainer cemented to the second deciduous molar (b) fixed lingual arch with adjustment loops. The arch is housed in lingual sheaths and may be removed for adjustment.

Extraction of the same tooth on the other side may be warranted to prevent centre line shift.

4. Early exfoliation of deciduous canines is most often the result and not the cause of incisor crowding. Centre line shift in cases of unilateral loss may be considerable. Extraction of the other deciduous canine is indicated. This does not mean necessarily that permanent extractions will be required ultimately.

5. Apart from esthetic considerations, early loss of deciduous incisors rarely requires space maintenance.

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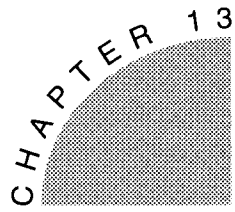
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DEMAND NEED AND MANAGEMENT

The definition of malocclusion is largely dependent on a concept of normal occlusion. While ideal occlusion is relatively easy to define, normal occlusion is not. At what point does a departure from ideal occlusion become abnormal. Orthodontic treatment is most often sought by the parent or patient to improve appearance rather than to improve oral health potential or occlusal function. Dentists, almost by definition, take a wider view of the potential handicap caused by malocclusion and recognise the inherent worth of an ideal occlusion. However, research suggests that individuals may survive quite comfortably with occlusions which depart substantially from the ideal. It cannot be claimed that orthodontic treatment is a major contributor to the prevention of caries, periodontal disease or temporomandibular dysfunction. In the absence of treatment it cannot be predicted that deterioration in oral health will definitely occur because of the presence of a particular malocclusion.

HEALTH AND FUNCTION OF THE MASTICATORY APPARATUS

Minor crowding of the lower incisors is so common as to be regarded as normal. When the crowding becomes excessive and is unsightly it is then regarded as abnormal. The cut-off point between normal and abnormal is impossible to define and will usually vary from one examiner to another and from one patient to another. While it may be easier to effect good oral hygiene in the absence of crowding, efficient oral hygiene will compensate for the impediment caused by crowded teeth in many cases. Thus the benefits of orthodontic treatment in terms of oral health may be elusive and perhaps even illusory. When the longterm instability of some treatment is also considered, the clinician bears the responsibility in reaching a balanced opinion about the need for orthodontic treatment.

Horup et al (1987) have proposed that attempts to define a conclusive causative relationship between malocclusion and oral disease may be confounded by a complex interaction between malocclusion, perceived malocclusion, personality traits and dental behaviour. They drew attention to a significant correlation between retention of teeth and satisfaction with dental appearance. They suggested that dissatisfaction with appearance due to malocclusion leads to decreased interest in dental health which in turn leads to neglect and ultimate extraction of teeth rather than conservative treatment.

Argument persists concerning the relationships between malocclusion, orthodontic treatment and temporomandibular dysfunction. Mohlin and Thilander (1994)

discussed the complexity of relationships between mandibular dysfunction, social and personal factors and malocclusion. They reported a significant correlation between dysfunction and Class III malocclusions, balancing side interferences, crossbites associated with a mandibular slide and anterior openbite. However, Greene and Laskin (1988) highlighted the lack of compelling epidemiological evidence to support predictable associations between dysfunction and malocclusions of various types. Orthodontic patients should be carefully counselled against the expectation that orthodontic treatment will prevent or cure dysfunction. Many studies have shown that orthodontic treatment cannot be prescribed as a cure for dysfunction. Neither has orthodontic treatment been shown to be a cause of dysfunction. Malocclusion in general does not seem to be associated with significantly reduced masticatory efficiency although individual patients will express dissatisfaction with chewing problems due to crossbite, openbite and severe individual tooth malpositions.

The association between poor speech and severe dentofacial deformities such as cleft palate is accepted. Severe Class III malocclusions may cause speech defects due to difficulty in achieving a linguo-dental seal. Normalisation of skeletal relationships may give significant speech improvement. But there does not appear to be any consistent relationship between particular malocclusions and particular speech defects. The presence of anterior sigmatism (lisp) in association with an openbite cannot be confidently predicted to disappear after treatment of the openbite.

DEMAND AND NEED

The professional assessment of treatment need is guided by assessment of oral health risk due to morphological and functional factors. But the patient's demand for treatment is largely determined by dento-facial appearance. In broad terms there will be a good correlation between appearance, severity of malocclusion and professional recommendations for treatment. However, particular malocclusions such as a maxillary diastema may rate low on the professional recommendation scale yet generate a high level of demand by the patient. Fisk (1960) noted that it is the significance of the malocclusion to the patient that is responsible for motivation and the demand may be disproportionate to the physical condition.

The interactions between dentist, parent and patient in determining need are complex and will lead to disagreements. Careful discussion with the patient and parent before venturing an opinion may be more rewarding for all concerned. But that does not absolve the dentist of the responsibilities of proper explanation to allow the patient or parent to reach an informed decision. Nevertheless, many parents and patients simply want an honest evaluation of the risk outcomes of the problem rather than an automatic recommendation for orthodontic treatment.

The dentist will be required to advise the patient on the issues of oral health and function. The dentist must also attempt to evaluate need in terms of the possibility of achieving a successful outcome. It is a pointless exercise to extract four bicuspids

prior to treatment only to find the patient will not go on. The dentist must attempt to reach a balanced opinion based on a knowledge of the support the child will receive from the family, the economic circumstances, possible cooperation and dental health status. The single most important cause of failed orthodontic treatment is lack of cooperation – either total or partial. This issue must be addressed squarely.

Psychological well-being is a difficult issue to argue in terms of need for orthodontic treatment. Some children seem to suffer unduly from disfiguring malocclusions. The extreme examples arise with cleft lip and palate. Shaw et al (1980) found dental appearance to be the fourth most common cause of teasing after height, weight and hair appearance. Jenny and Proshek (1986) concluded that a barrier to future career opportunities may result from a dental appearance which deviates from the acceptable norm, particularly in the highly visible professions, although other studies have found no significant association between occupational status, socioeconomic status and the presence of malocclusion. Overall it may be concluded that dento-facial abnormalities will have an unfavourable psychosocial effect on some individuals but the association is not predictable.

The need for orthodontic treatment in any individual will clearly be related in some way to the measurements of particular variables but the relationship is difficult to define. Do several mildly abnormal variables equal one moderately abnormal variable? Further complication arises if the patient's appreciation of the particular malocclusion is somehow added into the equation to be considered along with the assessment by the dentist or orthodontist. We see, therefore, that any estimation of severity or treatment need will be impossible to validate because there are no stable baselines which may be used to define boundaries between levels of severity or need.

PREVALENCE OF MALOCCLUSION

Some previous studies have attempted to subjectively assess malocclusion on a severity scale such as severe, moderate, minor and normal. The difficulty with this type of study is that the distinction between categories is unstable and dependent on many factors and will vary from one time to another. An alternative method is to select and measure a group of descriptive variables such as overjet, overbite and molar relationship. These variables are then measured for every member of the sample and sample statistics derived.

Freer and Olive (1976) studied a random sample of 522 Queensland schoolchildren and found prevalence rates for Angle's classes as shown in Fig. 1. In the same group using a ten point subjective severity scale they estimated approximately 23% of cases warranted treatment (scores > 6) bearing in mind this was a subjective estimate and there were no cases of cleft lip and palate or other severe craniofacial malformations (Fig. 2). In Western countries, approximately 35% of the population could benefit from orthodontic treatment but some cases would be classified as

mild. Approximately 20% of the population could be considered to have a moderate treatment need, while approximately 10% could be considered to have a severe to very severe malocclusion. The difference between treatment need and treatment demand is an indication of the different perceptions of dentists and patients. Fisk (1960) classified patients presenting for orthodontic treatment and found that approximately 60% had a Class II malocclusion. This would suggest that Class II malocclusion is perceived to be more undesirable than other types.

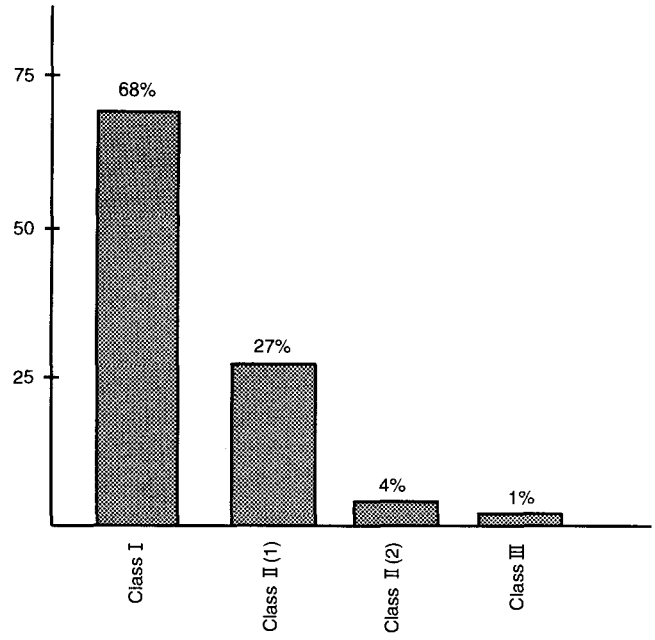


Fig. 1: Distribution of Angle's classes in a sample of 522 children.

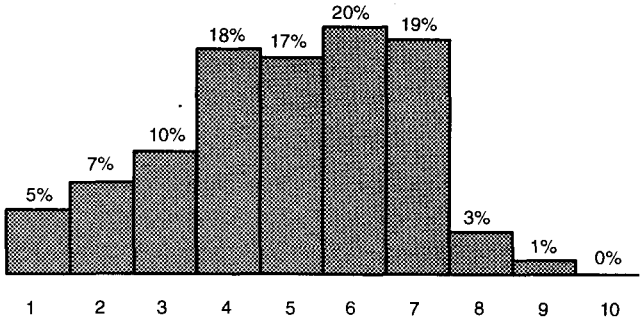


Fig. 2: Distribution of severity ratings in a sample of 522 children.

INDEXES OF MALOCCLUSION

We have already looked at the DAI index as an example of an index of malocclusion. Any objective screening system used to determine need for treatment must be clinically robust and must accurately reflect scientifically founded evidence to support the benefits of treatment. It should also reflect the psychosocial benefits of treatment from the patient's viewpoint. Unfortunately both objectives have largely eluded researchers and all of the present indexes of malocclusion are liable to result in significant and unacceptable misclassifications of persons seeking orthodontic treatment. Unfortunately, administrators are much in favour of the apparent numerical exactitude falsely proferred by indexes of malocclusion simply because once a "number" is derived it is difficult for the unskilled or unknowing person to argue with the outcome. It is well known that the levels of agreement between clinicians regarding the need for treatment are brittle. In general terms, agreement levels of 80 percent between examiners are very good leaving 20 percent of any sample where opinions are likely to differ. Admittedly agreement levels at the very good and very bad ends of the assessment scale are more robust but toward the middle of the scale disagreement increases (Freer, Grewe and Little, 1973). But the malocclusions at the middle of the severity scale are those where the benefits of treatment become more difficult to define. Indexes are not capable of becoming more accurate than the information from which they were constructed – a point often obscured by the demands of health administrators seeking to simplify and "objectify" the evaluation process.

Solow (1995) has re-examined the matter of treatment need and discussed the concept of "quality of life". He points out that that many conditions may detract from the quality of life but may not be a health risk. In those communities where treatment is funded by a third party (which may include the public service) it is necessary to distinguish between treatment to improve oral or psychosocial health and treatment to improve the quality of life. The evaluation of oral health risk may be better undertaken by relatively simple criteria which avoid metric or numerical estimates of severity as provided by an index. Much orthodontic treatment is simply directed to an improvement in the quality of life but the increasing demand for orthodontic treatment may dictate that third party funding will be confined to the treatment of proven health risks.

One of the enticing aspects of an index is that it provides a numerical indicator which is unaffected by personal bias apart from the errors of measurement of the components of the index. The epidemiological data obtained from an index are perfectly valid for comparative purposes across populations. Whether an index measures what it purports to measure is another matter. Where an index purports to measure need for treatment, the basis for the claim must be proven beyond reasonable doubt. All known indexes of malocclusion provide a broad guide to treatment needs but none may be used confidently as the sole determinant of individual need.

PREVALENCE OF MALOCCLUSION TRAITS

Broad ranging standardised studies of the morphological traits of malocclusion are relatively uncommon and amongst the more important studies are those of Helm (1968, 1970). The work of Helm provides valuable bench marks for population comparisons of the prevalence rates of specific anomalies. However, such comparisons have not been widely undertaken. It must be remembered that prevalence rates of specific traits are not necessarily an indication of the need for orthodontic treatment. Some traits while present and therefore recorded, may not be considered to be in need of treatment. This point should be borne in mind when comparing the result of different studies of malocclusion based on very different criteria.

Helm (1968) described three types of anomalies of occlusion as follows:

Dentitional – formation, eruption and alignment

Occlusal (spatial) – saggital, vertical and transverse

Spacing – crowding or spacing

The presence of any one of these anomalies may technically be regarded as a malocclusion. Helm found anomalies in about 78% of the sample but it should be observed that many of these anomalies would not be considered to be in need of orthodontic treatment and therefore his estimate is not to be regarded as an indication of treatment need. Of interest are the data on spatial anomalies (Table 1) from the same sample. These would provide a more robust estimate of need for treatment. However these figures do not compare directly with the estimates previously discussed because the same case can appear in more than one category.

		Boys(%)	Girls(%)
Saggital	Extreme maxillary overjet	15.9	12.5
	Mandibular overjet	0.7	0.3
	Distal molar occlusion	23.2	25.8
	Mesial molar occlusion	4.1	4.5
Vertical	Incisal open bite	2.3	1.8
	Incisal deep bite	22.7	14.5
	Lateral open bite	0.4	---
Transverse	Crossbite (lingual)	9.4	14.1
	Scissors bite (buccal)	7.1	7.9

Table 1: Frequencies of saggital, vertical and transverse (spatial) anomalies in a sample of 565 boys and 675 girls in the adolescent dentition stage (DS4) without orthodontic treatment or extractions (Helm, 1968).

MOTIVATION

Motivation of patients to cooperate during treatment may be improved by careful explanation of the aims of treatment and the appliances to be used. Realistic estimates of treatment periods will give the child and parent a specific goal. Motivation in the presence of sheer disinterest is a difficult or impossible task and the tendency is for the operator to delude himself or herself in the interests of the child. A failed orthodontic treatment program, particularly where extractions have been done, may leave the patient worse off than before treatment.

The timing of treatment is an important and underrated consideration. Children in the pre-teen and early teenage years are dentally, physiologically and socially able to cope with the inconveniences of orthodontic treatment. Most types of treatment in the adult will be more difficult and some types of treatment may even be practicably impossible in the adult. It is the dentist's responsibility to ensure that the patient is well advised on the issues of timing and options. But orthodontists face a special problem in the matter of consent in that the great majority of their patients are young and the decision to start treatment is made by the parent. Children will often disagree with parents concerning the need for treatment. This problem becomes more evident in the teenage years when children begin to assert their independence. Whilst parents may be enthusiastic about treatment, there is often little to be done to convince reluctant teenagers that they should seize the opportunity to undertake treatment at a time when they have fewer responsibilities and perhaps are still growing.

The need for orthodontic treatment must be assessed in conjunction with the likelihood of successfully completing treatment. Most orthodontists spend considerable time in patient evaluation, matching the patient's expectations with parental support, likely cooperation, oral health status and the difficulty of treatment. The treatment plan must be applicable to the particular patient's circumstances. It is pointless to begin a non-extraction treatment for a Class II malocclusion which is totally dependent on headgear wear if the patient refuses to wear a headgear.

Orthodontic treatment will usually fail for one of five main reasons:

1. The most common reason is poor patient cooperation. Some children are capable of managing treatment with little help but many are largely dependent on parental support and guidance. Lack of parental support will often lead to a gradual deterioration in the child's interest. The operator must always assess potential cooperation. General oral care is often a good guide.

2. Inadequate instruction of the patient may result in a poor treatment response.

3. Unavoidable circumstances sometimes arise through difficulties within the family, illness or hospitalisation, trauma to teeth and unforeseen root resorption.

4. Inappropriate appliances.

5. Relapse after treatment may occur but rarely is the relapse complete. Some conditions, including rotations and poor axial inclinations, are more likely to relapse.

INSTRUCTION

Patients are very often apprehensive about the fitting of fixed and removable appliances. A sympathetic and sensitive dental nurse will be an invaluable ally in dealing with nervous patients and in providing instructions. The dental nurse must be given the confidence to provide feedback to the clinician in all phases of clinical management. Care must be taken to ensure complete understanding of the wearing, cleaning and caring for appliances. Particular attention must be paid to making sure the patient knows what to do in the event of pain or trouble due to breakage or a loose band.

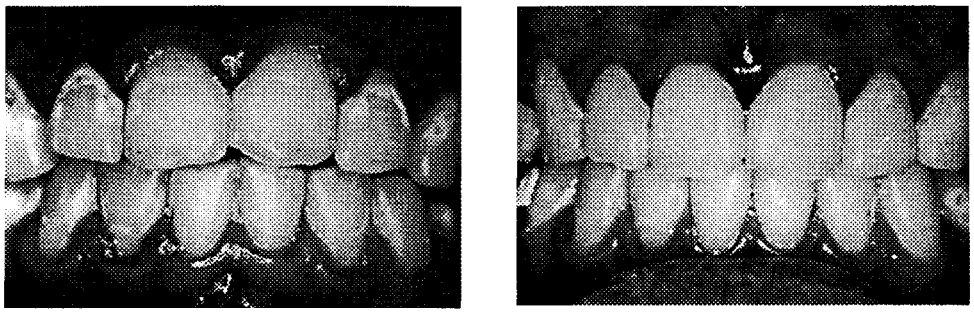
At the initial appointment check that appliances fit well and that there is no protrusion of wires or acrylic that is likely to cause ulceration of soft tissues. Where elastics are used, ensure that they do not pull against soft tissues and instruct the patient on this point. Be sure that there are no occlusal interferences and that bite planes contact a sufficient number of teeth and do not cause excessive and uncomfortable bite opening.

Patients should also be issued with copies of written instructions to cover all situations which might reasonably be expected to occur and they should feel welcome in contacting the office or the clinician in the event of difficulty. It may also be possible to provide video tapes for the instruction of patients.

DIET AND BREAKAGES

Caries and decalcification are major risk factors for some orthodontic patients where high levels of sugar intake cannot be controlled. Decalcification at the periphery of bonded attachments or under loose bands may reach alarming levels in some children in spite of every effort to prevent such an outcome with dietary instructions and the frequent application of topical fluoride (Fig. 3). Many children commence treatment with little or no sign of decalcification. As treatment progresses and the growth spurt commences, sugar intake may increase dramatically in some instances.

It is also a time of social experimentation with children becoming more independent and less responsive to advice. In some cases parents seem to have little or no idea of the child's diet or cooperation levels. The combination of disinterest and blatant non-cooperation may be truly discouraging to the clinician. Treatment begun for the most idealistic of reasons may have to be discontinued. Such an outcome is to be avoided if at all possible but the predictors are not reliable.



(a) (b)

Fig. 3: (a) After 18 months of fixed appliance treatment, areas of decalcification were particularly evident between the bracket attachment sites and gingival margins (b) the same patient seven months after the removal of fixed orthodontic appliances. Note the marked improvement in the clinical appearance of the lesions, particularly on the maxillary lateral incisors.

Usually breakages during fixed or removable appliance treatment are sporadic and due to unforeseen incidents or infrequent departures from instructions. A few children however literally attend most appointments with a breakage. Children who exercise least control of diet seem to be those reporting with most breakages. Often when questioned about their diet they will deny any misdemeanour and one such patient is remembered for leaving a number of toffees on the seat of the dental chair having vehemently denied ever eating sweets. Frequent breakages undermine the progress of treatment and in the worst cases may force the operator to discontinue treatment. Some children seem incapable of exercising responsibility of care for their appliances and even with a positive approach by the operator the progress of treatment may be seriously jeopardised. Functional appliances are an example. Being expensive to construct, the loss of one let alone two appliances will leave the operator out of pocket and with no progress in treatment.

ADULT ORTHODONTICS

Adults now constitute an interesting demand group in most orthodontic practices because unlike many children they seek treatment at their own initiation. Adult orthodontics has become much more common in recent years and reports suggest that adult patient loads in some practices are as high as twenty five percent or more (Gottlieb et al, 1991). More than 70 percent of adult patients are women and about 25 per cent of the adult group may be re-treatments. There is also a significant percentage of adults who seek treatment of prognathic malocclusions (Khan and Horrocks, 1991). Certain aspects of adult orthodontic treatment are in contrast to treatment in children and juveniles. Consultation technics with adults should be varied to provide maximum information directly to the patient and to ensure that the patient is an important participant in the formulation of treatment options. One simple strategy in this regard is to provide the patient with a copy of all

correspondence sent to the referring dentist, providing the correspondence is full and informative. This ensures all parties to the process are aware of recommendations. Issues requiring special consideration include caries and heavy restorations, periodontal problems, TMD symptoms and difficulties in treatment.

Periodontal health in adults may be compromised and orthodontic treatment in the presence of periodontal disease is likely to exacerbate the loss of attachment. A thorough periodontal assessment (clinical and radiographic) of adult patients is always required prior to treatment. OPG x-rays alone often do not provide sufficient information to assess bone support. Periodontal disease should be controlled prior to orthodontic treatment and periodontal maintenance during orthodontic treatment is also advisable. Adult orthodontics is playing an important part in the treatment of some periodontal conditions. Where teeth are in poor positions not allowing easy periodontal maintenance, orthodontic treatment can often help. A relatively common periodontal condition in adults is bone loss associated with drifting and spacing of the upper incisors. There may be deepening of the overbite as well. Routine periodontal treatment can do little for many of these cases in terms of stabilising the teeth. Orthodontic intrusion and retraction with reduction of the overbite, elimination of the spacing and retention may materially improve the long-term prognosis in these cases.

Completion of growth will often affect treatment objectives. The response to headgear and functional appliances in the growing patient may be dramatic but not in the adult. Treatment objectives tend to be more limited and directed to those specific factors which concern the patient. Additionally the presence of heavy fillings or root-canal treatments may dictate variations which make treatment more difficult. One of the main difficulties for adults is the correction of major skeletal discrepancies. Surgical treatment combined with orthodontic treatment has greatly improved results in these cases.

There are no basic limitations to tooth movement in adults although Barrer (1977) suggested that adult treatment is very testing in certain instances and the outcome of treatment is likely to be a compromise. Certain differences are noticeable. Tooth movement may be significantly slower in the early stages. Force levels must be carefully managed and excessive force is likely to cause undue pain. Many adults suffer considerable pain for one or two days after adjustment appointments. Interference with the occlusion which commonly occurs with multiple tooth movements may also cause considerable discomfort and bite opening procedures need to be conducted carefully.

Adult cooperation is usually excellent once the decision has been made to go ahead with treatment. However, the operator must be meticulous in explaining the difficulties of treatment and the likelihood that, in complicated cases, treatment time will usually be longer than for a child with a similar problem. Haynes (1982) showed that in Britain, incomplete treatment rates in adults are likely to be as high as 43 per cent although this is not supported by the work of Murray (1989). Adult

patients should be clear about the time that will be lost at work or in household duties. Adults are often very nervous about the effects of appliances on appearance and the possible social implications but these concerns usually quickly disappear once treatment has begun. The advent of colourless brackets has made the process much easier for some adults. The less obtrusive appearance of these attachments may be critical in their acceptance of treatment.

Orthodontic treatment may be requested as a precursor to fixed or removable prosthetic treatment. This may include tooth uprighting, space closure, space opening for a pontic or saddle area, space opening and root parallelling prior to making a bridge or doing an implant replacement. Close liaison and cooperative planning with colleagues is paramount in setting treatment goals in such cases. Where there is an overlying periodontal problem this will usually take precedence in the treatment chain and periodontal maintenance with home cleaning, professional maintenance and antibacterial agents will usually be intense during orthodontic treatment. If the patient is unable to establish periodontal health, orthodontic treatment may be contraindicated.

A diagnostic setup will provide an insight to the most practical solution in some cases where space closure or space opening are both options. Where tooth loss is longstanding and extreme narrowing of the alveolus has occurred in the extraction area, space closure may not be possible. Once uprighting of teeth commences careful examination for traumatic occlusal interferences should be routine and occlusal adjustment may be necessary.

The association between malocclusion and temporomandibular dysfunction is problematical at best. Patients with TMD who attend for orthodontic treatment should be specifically counselled that there can be no longterm guarantee of resolving the problem by means of orthodontic treatment. TMD symptoms may be relieved during treatment by reason of disturbance of the patients functional patterns but the improvement is likely to be transitory. In many adults the etiology of TMD is multifocal and there may be a significant psychological overlay. Careful evaluation with specialist advice may be advisable before any treatment is commenced. Orthodontic treatment should not be commenced in the presence of unresolved pain associated with the temporomandibular structures.

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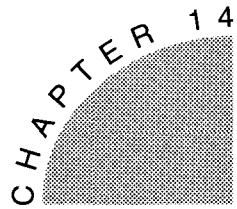
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PRINCIPLES OF CLASS II MANAGEMENT

Class II malocclusions are not usually discussed as a single continuous group. Diagnosis and treatment planning in contemporary orthodontics has been dominated by Angle's classification of malocclusion which is now 100 years old. Angle's classification distinguishes two major categories of Class II malocclusion – division 1 and division 2. Both involve disto-occlusion and often retrognathia of the lower jaw. However these generalisations do not reflect the complex relationships of the upper and lower teeth and jaws which may prevail in either category. Angle's classification has proven to be remarkably persistent. But it is a dental classification which does not necessarily reflect the underlying skeletal pattern. Modern orthodontic diagnosis and treatment planning are largely dependent on recognition of skeletal, dental and soft tissues patterns with the expectation that similar morphological patterns will have similar growth patterns and similar occlusal outcomes. Detailed cephalometric analysis of the morphology of Class II malocclusions shows a very wide range of combinations of morphological traits. The mathematical possibilities for unique combinations of traits are immense. Class II malocclusions contribute a high percentage of cases in the average orthodontic practice. They are also the subject of an extensive literature devoted to the concept of growth modification of the mandible.

CHARACTERISTICS

McNamara (1981) provided statistics for a mixed sample of Class II division 1 and division 2 cases. The total sample size was 277 children but details of Angle's sub-groups were not provided. Using the angle SNA as the criterion of maxillary antero-posterior position he found that only 14 percent of Class II malocclusions showed maxillary skeletal protrusion (SNA > 84 degrees) while 31 percent actually displayed maxillary skeletal retrusion (SNA < 79 degrees) and the remainder were within an acceptable normal range (Fig. 1). Using the angle SNB as an indicator of mandibular skeletal position he found that about 60 percent of the sample had a retruded mandible (SNB < 76 degrees) and the overall sample mean of 74.8 degrees (SD = 3 degrees) was well below the normal SNB value of about 78 degrees (Fig. 2). While there has been some disagreement with McNamara's percentages (Rosenblum, 1995), the implications of these statistics are very important and highlight the unsuitability of treatment in many Class II malocclusions where the principal aim is to retract the maxillary denture to occlude with an already retruded mandibular denture, particularly where that skeletal discrepancy is large. Where the discrepancy between upper and lower is not large, maxillary dental retraction may be an acceptable form of compromise treatment. However where the lower denture is very retrusive,

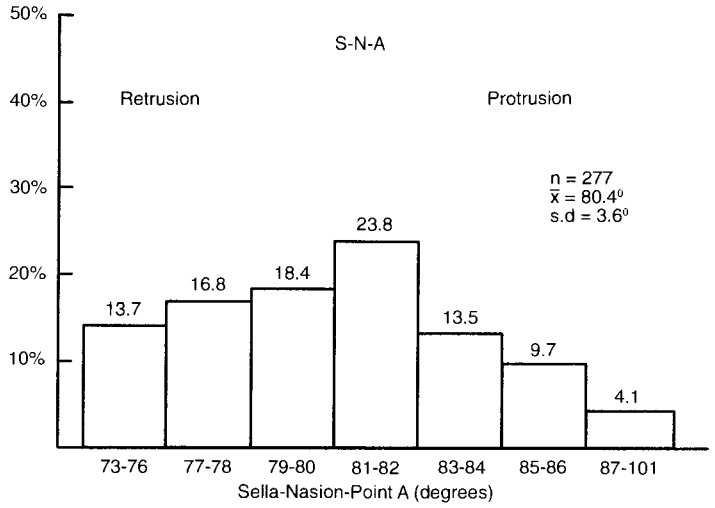


Fig. 1: Distribution of angle SNA in Class II sample. (Redrawn from McNamara, 1981.)

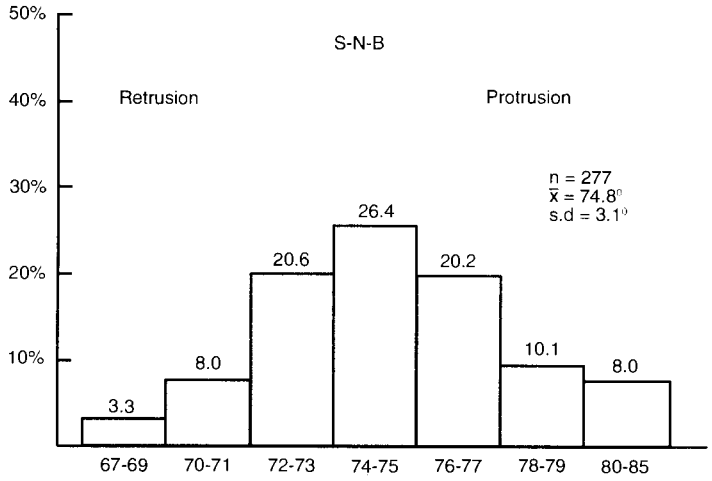


Fig. 2: Distribution of angle SNB in Class II sample. (Redrawn from McNamara, 1981.)

retraction of the upper denture is likely to give an unacceptable result with excessive lingual inclination of the upper incisors and a retrusive position of A point.

Statistics calculated from separate Class II division 1 and division 2 samples obtained at the University of Queensland Dental School broadly confirm the statistics of McNamara's combined group. Table 1 shows the means and standard deviations for a selection of standard cephalometric traits for our Class I, Class II division 1 and Class II division 2 groups.

	Class I		Class II (1)		Class II (2)	
	x	sd	x	sd	x	sd
SNA	80.6	4.0	81.0	4.1	80.9	3.7
SNB	77.9	3.9	76.1	3.7	75.9	3.6
APt Convexity	1.5	2.9	3.6	2.8	3.3	2.1
LIAPo	1.6	2.6	0.1	2.6	-3.3	2.7
MPA	25.6	4.5	24.8	5.8	22.7	5.5
LFH	44.7	4.2	43.8	5.1	41.2	4.4
Facial Axis	89.5	3.8	89.3	4.5	90.3	3.0
Facial Angle	88.7	3.2	87.3	3.2	86.8	3.7

Table 1: Means and standard deviations of cephalometric variables measured on Angles Class I, Class II division 1 and Class II division 2 groups of Queensland patients.

The differences between the means for these groups reflect the nature of the specific patterns but importantly the standard deviations imply considerable overlap and blurring of the differences between all three classes. In the Class II division 2 group there is a greater tendency to a brachyfacial pattern, squarer facial morphology and more retrusion of the teeth. These trends partially support the separation of Angles Class II division 2 as a distinct entity but the same distinction is not true of the Class II division 1 category. However there is a significant degree of variability and overlap in all categories which dictate careful individual analysis before finalising a treatment plan.

SUB-GROUPS

Moyers et al (1980) studied a sample of 697 children with Class II malocclusions and identified six subgroups based on antero-posterior maxillo-facial relationships. These subgroups were designated Types A,B,C,D,E,F and are graphically represented in Fig. 3. Type A displayed few typical Class II skeletal features but was so classified by a group of orthodontists because of the protraction of the maxillary dental arch with a consequential Class II molar relationship and increased overjet and overbite. There was little abnormality in the skeletal relationship in this group. Types B,C,D and E were reasonably well differentiated and stable groups. Type F however was a diffuse loose collection of cases with a mixture of various Class II skeletal characteristics. It is to be noted particularly that Type F cases comprised a relatively large 36% of the sample and in practical terms this means that a large percentage of Class II cases are not easily and consistently typed. Therefore diagnosis and treatment planning are likely to be more variable and difficult in this large group. The operator must carefully analyse the component parts of each malocclusion in reaching a treatment plan. The application of a standardised treatment protocol is particularly undesirable in the Group F cases.

There is a range of vertical anomalies that may occur in association with the horizontal Class II types described above. Moyers et al (1980) found some stronger associations between specific vertical and horizontal types. For example horizontal

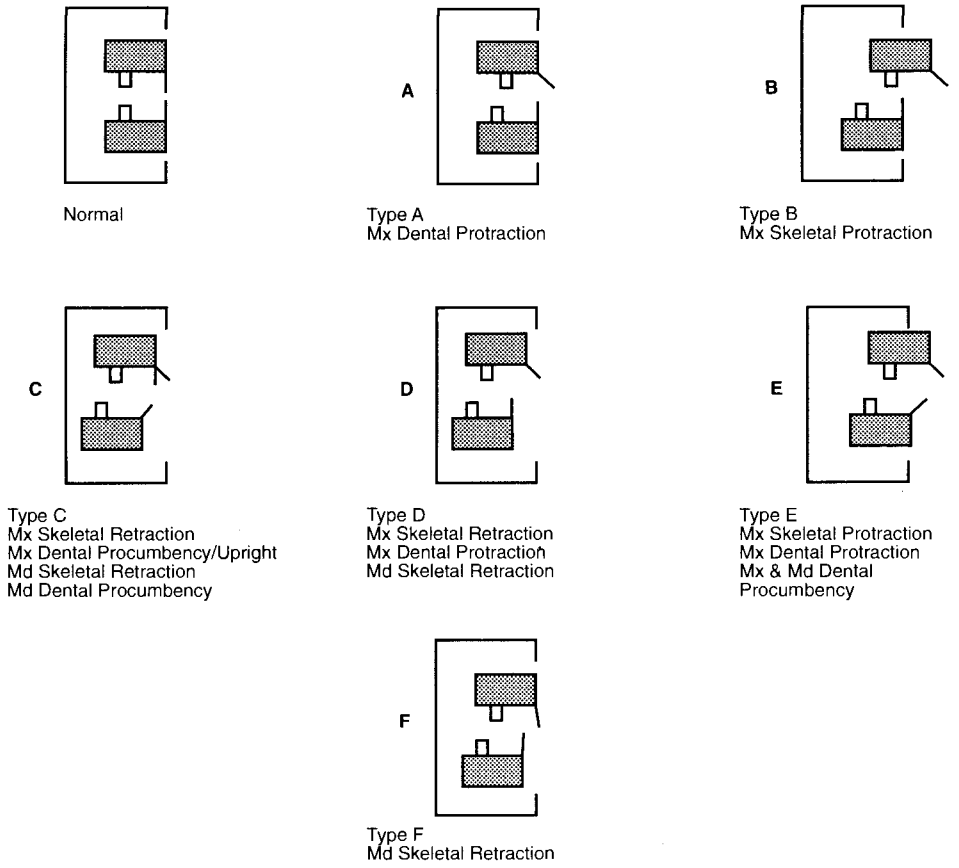


Fig. 3: Representations of Class II horizontal skeletal types based on the respective skeletal and dental relationships to the cranium (Moyers et al, 1980).

types B and E are found in skeletal deep bite cases with square faces. They warned that each horizontal type might occur with one of several vertical types and found that the vertical types are not as clearly differentiated as some of the horizontal types. For these reasons there are practical advantages in continuing to use Ricketts' classification of facial types – mesofacial, dolichofacial and brachyfacial. Several variables (Table 1) including the Frankfort mandibular plane angle (MPA) and the lower facial height (LFH), are reflective of the vertical skeletal morphology. The standard deviations of these variables however suggest considerable morphological overlap. For example the Class II division 1 group has a mean MPA value of 24.8 degrees and a standard deviation of 5.8 degrees. These statistics do not reveal that the minimum value seen in the sample was 6 degrees and the maximum value was 57 degrees. Similarly the mean and standard deviation for lower facial height (LFH) were 43.8 and 5.1 respectively but the minimum and maximum values were 32 and 65 degrees respectively. Clearly therefore the clinician must be prepared to examine the detailed morphology of the case before finalising the treatment plan.

ETIOLOGY

The relationships between the skeletal, dental and soft tissues in the individual raises the important issue of etiology. Are Class II problems the result of aberrant environmental factors? Disregarding pathological and abnormal functional conditions for the moment, the etiology of individual Class II skeletal anomalies is difficult to prove with certainty although contemporary evidence suggests they are inherited and sometimes modified by environmental factors. It is not understood how environmental and functional factors interact to influence inherited patterns. Some soft tissue patterns are due to a primary abnormality of the supporting skeletal structures. In such circumstances normal function of the soft tissues may be difficult to achieve thus leading to adaptive soft tissue function which in turn leads to further deterioration of the already abnormal dental pattern. In yet other cases the soft tissue functional pattern seems to be the primary etiological factor causing a modification of dento-alveolar development and relationships not seen in comparable cases with a normal pattern of activity. In the 1960's British orthodontists devoted a great deal of attention to dento-facial soft tissue patterns and activities raising many questions which have never been satisfactorily addressed and yet largely ignored in the move to non-extraction expansion and functional treatment which became so prevalent some fifteen years later. Yet those questions remain relevant today.

Studies of identical twins are potentially very useful in studying the etiology of malocclusion because they provide natural controls particularly where the dental patterns in identical twins seem to differ because of different functional patterns. Leech (1955) reported identical twins with Class II malocclusion, one being division 1 and one being division 2. The occlusal difference, it was suggested, resulted from a difference in the functional muscle patterns of the lips and tongue between the twins causing proclination of the incisors in one twin. Briggs (1963) showed occlusions in a pair of identical twins aged 10 years. Their soft tissue and skeletal morphologies were very similar. One twin had sucked the right thumb continually from soon after birth to the time of examination and had a Class II division 1 malocclusion. The other twin had never sucked her thumb and had a Class II division 2 malocclusion. Detailed examination of their histories and general skeletal and soft tissue morphologies suggested that the thumb sucking habit was the most significant difference between them and had pushed the upper incisors outside the control of the lower lip. Cephalometric analysis revealed a slightly more retrognathic mandible in the twin who had never sucked her thumb. Examples such as these may provide evidence in favour of the value of interceptive procedures although not of the potential of orthodontic treatment to alter basic inherited skeletal or soft tissue morphologies.

While some soft tissue activity patterns are thought to be adaptations to the underlying skeletal abnormality, Ballard (1963) showed that facial patterns such as sling-like retraction of the lower lip and some forms of tongue thrusting are probably inherited traits and therefore less amenable to interception. Soft tissue patterns are notoriously

difficult to measure accurately, particularly functional parameters. The clinical evidence suggests that soft tissue patterns and relationships in Class II malocclusions are every bit as variable as the associated skeletal types. The major difficulty for the clinician is how to determine with reasonable certainty the difference between adaptive and inherited soft tissue activities thereby providing a more predictable basis for interception.

A great deal of research has been directed to the relationships between vertical development and environmental influences. Some investigators suggest that anterior open bite is related to mandibular opening and tongue posture which are associated with hyper-eruption of posterior teeth. Unfortunately when the morphology of openbite cases is examined in detail it is not possible to demonstrate consistent cause and effect relationships of this type. But the methods available for accurate measurement of muscular function are relatively crude. Evidence from pathological entities would strongly support the notion of considerable variation in the size, structure and function of the muscles of mastication. Most research in orthodontics has concentrated on osseous morphology and relationships without any real clarification of whether muscles are critical determinants of dento-facial form in the absence of frank pathology. One might also expect a high level of heritability of muscular patterns and this is demonstrated in certain types of dysplasia.

TREATMENT PRINCIPLES

The treatment of all Class II malocclusions requires consideration of both the horizontal and vertical skeletal patterns prior to correction of the buccal segment relations by means of relative distal movement of the upper arch or mesial movement of the lower arch. The vertical dimension is an important but often ignored component of the assessment analysis. Treatment of Class II problems caused by maxillary skeletal protrusion is conceptually much simpler to plan because correction may be achieved by restraint of forward development or distal movement of the upper arch by means of headgear or biomechanics which do not cause undue reciprocal forward development of the lower arch. As a compromise, extractions in the upper arch only will achieve a similar end although other objections may be raised to this solution.

Treatment of Class II problems resulting mainly from mandibular skeletal retroposition is more difficult to achieve without excessive proclination of the lower incisors to an unstable position. Where the upper incisors are trapped outside the lower lip prior to the commencement of treatment, some lower proclination may provide an acceptable result. The outstanding question is whether functional protraction devices are capable of inducing a true increment in mandibular growth beyond that normally expected. These devices include the Andresen monobloc, Frankel appliance, Herbst appliance, twin block and bionator and others. Where the particular malocclusion is due to a mixture of maxillary protraction and mandibular retrusion slight reciprocal correction in both arches may achieve an acceptable result

both functionally and esthetically. Often the balance of treatment objectives will be determined by patient cooperation as much as anything else.

Some forms of Class II skeletal treatment such as heavy orthopedic headgear treatment do have an effect on the surrounding bones and sutures with restraint of development of the maxillary complex. But longterm observation again suggests that a gradual reversion to the original skeletal pattern occurs in many cases and the residual lasting orthodontic effects are due mainly to dento- alveolar changes.

Whilst the skeletal pattern of each particular case is fundamental to treatment planning, the associated soft tissue morphology is also important in setting treatment objectives. For example in some Class II problems the mid-facial region may be within normal limits but the mandible may be retrusive. If the upper incisors are upright before the commencement of treatment, further retraction and lingual inclination may cause a deterioration in soft tissue profile appearance. Such cases may be better not treated, particularly if the patient is not concerned and function is acceptable. If treatment is to be undertaken the option of orthognathic surgery should be considered. This may not be acceptable to the patient. Postponement of compromise orthodontic treatment will offer the patient a chance for more effective treatment at a later date. In other cases where the soft tissues and lips are full and rounded with a good profile and outline, the clinician may be justified in pursuing a treatment plan which otherwise might not be ideal. In all cases the clinician must balance the needs of the patient with the potential outcomes of treatment based on a thorough assessment of all aspects of the associated structures and tissues.

BROAD OBJECTIVES

Certain principles of treatment may be proposed. Where there is significant maxillary skeletal protrusion, biomechanics directed at maxillary restraint or maxillary incisor retraction are more acceptable. Where there is mandibular skeletal retrusion without maxillary protrusion, treatment if possible should avoid excessive retraction of the maxillary arch to the mandibular arch. Evaluation and treatment are often subject to compromise and if the skeletal discrepancy is not marked the operator may be justified in pursuing compromise treatment. This is particularly true where the soft tissue covering is full and might be more forgiving of some maxillary retraction. However, where the soft tissue morphology and profile outline is compromised before the commencement of treatment then the operator must consider the deleterious effects of any treatment which will over-retract the upper lip outline and increase the nasolabial angle.

Treatment inducing forward development of the mandible is a controversial topic in orthodontics. The available evidence suggests that it is not possible to cause the mandibular body to grow beyond a genetically determined limit and the effects of such treatment are more in the nature of redirected growth or development. At the end of the retention/growth phase there may be little permanent gain beyond that

seen in untreated subjects. Neither is there any evidence to suggest that active and aggressive expansion of the dental arches in order to overcome crowding is likely to remain stable. Where the soft tissue environment is substantially changed by treatment, small to moderate increases in arch dimensions may be justified. Orthodontic studies of the longterm outcomes of growth modification are sparse. Controlled studies are very uncommon. Unless treatment philosophies can be scientifically validated, one must remain cautious about claims of predictable and stable growth modification of the mandible. It is well known that brachyfacial skeletal patterns are likely to respond favourably to growth redirection because of the nature of mandibular growth in these cases. However, cases exhibiting a high mandibular plane angle and a tendency to anterior open bite may be predicted to relapse at least partially with a re-expression of the underlying genotype. These are the cases where the growth direction is unfavourable to correction of the malocclusion.

Functional appliances are certainly capable of inducing longlasting changes in the dento-alveolar areas with a subsequent improvement in the orofacial functional environment and promotion of optimal development within genetically determined limits. Much of the treatment change in Class II skeletal problems is associated with maxillary dento-alveolar retraction and mandibular dento-alveolar protraction. On average, the upper incisors become more retroclined and the lower incisors become more proclined. Once again the clinician must weigh the benefits of treatment effects against the disadvantages including the potential for relapse. If the lower incisors are proclined excessively then relapse with crowding is almost certain to occur. Ultimately a stage will be reached where the severity of the case demands correction by joint orthodontic treatment and orthognathic surgery.

It should be borne in mind that Class II treatments are not always successful and many seemingly successful treatments relapse – at least partially. This highlights the importance of longterm case follow-up before claims of the superiority of any particular form of treatment are accepted. Experience demonstrates that the more extreme malocclusions are much better treated by a combination of orthodontics and orthognathic surgery or if that is not possible, no treatment may be the wise option, at least for the time being. Finally the comparability of treatments between patients is always subject to the effects of patient compliance which is sometimes excellent, sometimes reasonable and often questionable. Comparability is also compromised by the absence of truly balanced control groups in most experimental designs because clinicians are not justified in refusing treatment for the purposes of scientific investigation.

HEADGEAR

Headgear is used in the treatment of Class II malocclusions for three main purposes (a) reinforce anchorage and prevent unwanted forward movement of the anchor teeth (b) actively retract the upper first permanent molars to a Class I relationship

with the lower molars before finally correcting the relationships of the anterior teeth (c) orthopedic restraint of the maxilla and upper dento-alveolar structures.

The wire bow of the headgear consists of an inner bow made from approximately 1.0 mm wire and soldered to the outer bow made from approximately 1.25 mm wire. The inner bow fits into the large tube on the molar band and is limited in its travel by either a bayonet bend or a large U loop. The outer bow of the headgear is attached to a cervical neck strap or a headcap by means of an elastic strap or a spring mechanism. The outer bow may be varied in length but conventionally extends distally beyond the site of insertion of the inner bow into the molar tube.

Headgear is usually attached to the upper first permanent molars and three basic force systems are used including cervical (low pull), occipital (high pull) and combination (straight pull) types. The cervical headgear uses a simple neck strap attached to the outer bow. The net force vector is down and back, below the centre of resistance of the molar, generating both distal and extrusive components. A cervical headgear will always exert an extrusive force on the molar. Depending on the magnitude of the force applied, the extrusive component may be cancelled out by occlusal forces. Excessive cervical forces will cause extrusion of the molars with consequent occlusal interference leading to posterior rotation (opening) of the mandible. Posterior rotation causes the mandible to open both down and back.

As the line of headgear pull is raised using either a straight pull or high pull headcap the force passes closer to, through or above the centre of resistance, at about the centre of the root trifurcation of the first permanent molar. Extrusive forces are thereby minimised or eliminated. The high pull headgear may achieve modest depression of the molar. The analysis of force vectors of headgears is very complex. It is often forgotten that whether the outer bow is raised or lowered even though the traction strap attaches to the outer bow, the actual point of force delivery to the tooth is at the inner bow/molar tube (Fig. 4). So far it has been assumed that the first molars only are banded. If all the teeth in the arch are connected by an arch wire, the centre of resistance of the block of teeth lies further forward from that of the first molar alone and the action of the headgear will now be modified by the line of force relative to the new centre of resistance. High pull headgear may also be attached to a removable or functional appliance when it is considered desirable to attempt to limit vertical development of the upper arch – perhaps in the presence of an anterior open bite. A cervical headgear would not be desirable for several reasons including its tendency to displace the appliance.

The performance of the cervical headgear will be altered by the position of the end of the outer bow relative to the inner bow and therefore the first permanent molar. Where the outer bow is longer than the inner bow, bending the outer bow up to a higher position than the inner bow will induce distal apical rotation and extrusion of the first molar. Bending the outer bow down to lie below the inner bow may induce distal crown rotation and some extrusion. If the outer bow is made shorter

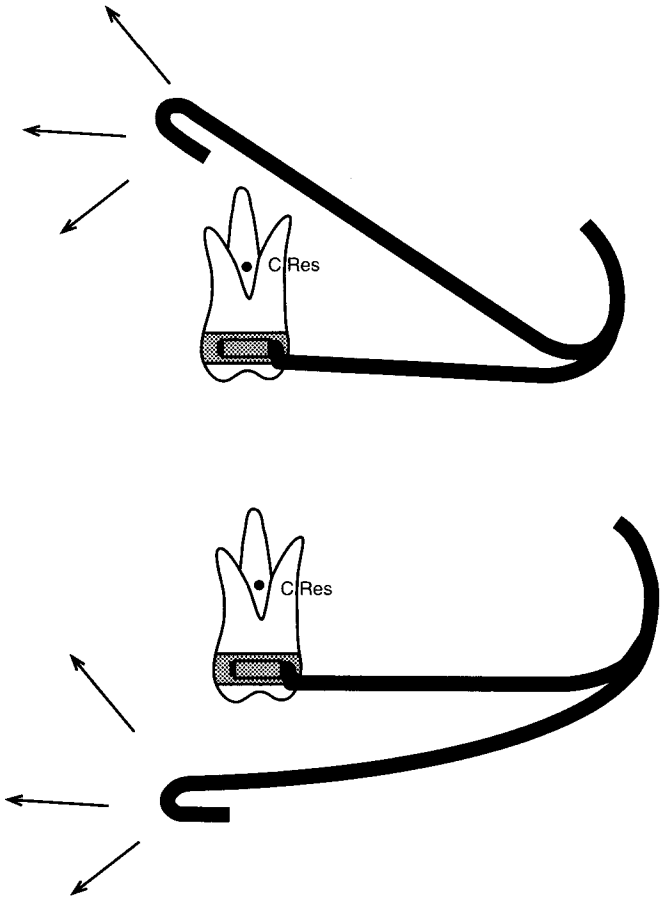


Fig. 4: Attachment of the inner headgear bow to the first permanent molar. The outer bow may be positioned above or below the molar tube.

than the inner bow, the effect will depend on whether the line of pull is above or below the centre of resistance of the molar and this will further depend on the type of headcap or strap used to deliver the force. The particular headgear used must be consistent with the treatment objectives which are determined by the skeletal morphology of the case. In very general terms we may say that the use of cervical headgear should be limited in dolichofacial types or where the depression of teeth is desirable.

Depending on the vertical skeletal pattern of the particular case being treated, extrusion may be desirable or undesirable. In the actively growing brachyfacial type with a deep bite some careful molar extrusion may even be encouraged consistent with the incisor intrusion and bite opening mechanics. But as the pattern becomes more dolichofacial with vertical skeletal excess or a tendency to openbite then the direction of headgear pull should be raised above the centre of resistance to minimise undesirable elongation effects on the molars or to induce intrusion.

Recommended force levels applied to the headgear vary considerably from 200 to 500 grams per side. Lighter forces are recommended for anchorage maintenance while heavy forces are recommended for an orthopedic effect. In most cases a force of 250-300 grams per side will produce good molar movement providing the patient cooperates. It is difficult to understand how a longterm force of 500 grams or so will not cause root damage but the intermittent nature of the force application probably rests the tooth sufficiently to prevent permanent damage. However, from time to time resorption due to headgear wear has been reported. Hours of wear must be explained to the parent and patient. It is a practical help to have the patient keep a log of hours of wear. Less than 14 hours a day is unlikely to achieve positive Class II correction. Wear at school is problematical due to the safety issue and the possibility of damage at play or because of interference by other students. The occasional patient will wear a headgear in excess of 20 hours each day and the response is usually inspiring. It also suggests that the lack of response in many patients is due to insufficient wear in spite of the protestations of the patient and the parent.

In recent years the matter of safety and headgear wear has become better documented. While safety precautions have always been paramount, reports of injuries have been sporadic. A recent article (Samuels and Jones, 1994) suggests that injuries are more common than is widely believed. Various safety designs and devices including release mechanisms have been marketed. Eye injury is likely to be the most serious problem because the width of the inner bow is similar to the inter-ocular width. Eye injury may occur at night if the appliance becomes detached from the molar bands and the patient rolls over on the bow. It seems one of the most effective safety devices in this regard may be a simple plastic safety strap which prevents the headgear bow from becoming unhooked. It is critical that the clinician address this issue with the patient as part of the informed consent process.

FUNCTIONAL APPLIANCES

The monobloc, bionator, twin block and Frankel appliances (amongst many others) are functional devices which require a forward bite registration of the lower to the upper jaw and derive their corrective action from the stretch reflex of the muscles. The patient may remove the appliance but it should be worn as much as possible and certainly in excess of 16 hours every day. The Herbst appliance also requires a forward bite position but it cannot be removed by the patient. Its constant action usually guarantees rapid correction but the appliance suffers from some difficult management and breakage problems which detract from its popularity. Clearly all these devices are most efficiently used in the correction of Class II division 1 malocclusions with an increased overjet. Even in Class II cases with crowding which will ultimately require extractions, a preliminary phase of buccal segment correction with a functional appliance may make subsequent fixed appliance treatment much easier. Given the structural similarity of the skeletal morphology of some Class II division 2 and division 1 malocclusions, it is realised that functional appliance

treatment of some Class II division 2 cases may also be desirable. This is achieved by a phase of upper incisor proclination to a division 1 relationship.

Case selection for successful functional appliance treatment of Class II malocclusion is usually limited to mesofacial to brachyfacial morphologies. Brachyfacial types are known to respond very favourably and in some actively growing brachyfacial cases the dento-alveolar response may be almost startling. As the morphology becomes more dolichofacial with a tendency to vertical excess and openbite, the recommendation for functional appliances becomes less confident as the expected growth pattern becomes more vertical. This again raises the issue of the effects of functional appliances on the the growth pattern. If they are able to redirect abnormal growth why are they less effective in dolichofacial types? Why can't we "change" growth in these cases also? In addition, as the growth rate decreases the effect of a functional appliance is less predictable.

Most children will wear a functional appliance with little inconvenience. In the mixed dentition, often a good time, adjustment for the continuing loss of teeth is usually required and sometimes a new appliance is needed. Occasionally, cooperation is poor and correction is very limited. If substantial improvement is not gained in three to six months the operator should become suspicious of cooperation. In older patients, persistence with the functional appliance in the face of poor cooperation may waste precious time. A change in treatment plan and appliances may be required.

REMOVABLE APPLIANCES

It is first necessary to distinguish functional appliances from removable appliances. The term removable appliance refers to single arch devices which do not rely on muscular action for their effects. In selected Class II malocclusions with an increased overjet, Class II buccal segment relationships, an acceptably aligned lower arch, maxillary skeletal protrusion and favourable incisor angulations, consideration may be given to extraction of the upper first bicuspids with retraction of the upper canines first followed by retraction of the the upper incisors to the lower incisors. This in effect camouflages the dominant maxillary skeletal pattern and reduces the overjet without compromising the facial appearance. As mandibular retrusion becomes more dominant, upper incisor retraction causes over-retraction of the upper lip with a deterioration in appearance. With careful case selection, compromise treatment of Class II division 1 malocclusions with removable appliances can be very successful.

Compromise solutions may yield acceptable results but ultimately the magnitude of the skeletal discrepancy or the unacceptability of the underlying incisor angulations will mitigate against achieving a good result and other treatments will be required. Class II division 2 malocclusion is characterised by deep overbite and a significantly increased inter-incisal angle with retropositioning of the upper and lower incisors on their respective bases. An orthodontic case with these characteristics cannot be successfully treated with removal appliances which are incapable of controlling the

vertical position of the upper incisors and of the angulations of the upper and lower incisors and therefore the inter-incisal angle. If teeth are extracted to alleviate the crowding which is usually present in the upper arch, correction is limited to simple alignment using the spaces created by extractions. Treatment requires appliances which are capable of selective control of the vertical and angular positions of the teeth. In addition, the expected mandibular growth pattern in the brachyfacial type is more horizontal and this will very often provide the impetus for successful nonextraction treatment with a good stable interincisal angle.

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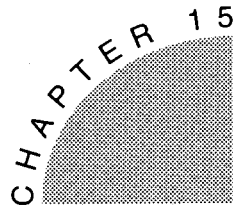
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Class II Division 1 Malocclusion

Class II division 1 malocclusion was defined by Angle as any malocclusion with a Class II molar relationship greater than half a cusp displacement and protruding upper incisors. Detailed examination of the facial structure in Class II division 1 malocclusions reveals a wide variation in the underlying skeletal morphologies. There is a large number of potential combinations of horizontal and vertical skeletal types as well as varied soft tissue and dental patterns. With the continued use of Angle's classification it is necessary to spell out the modifying factors which will influence the clinicians judgement and treatment options. Additionally there may be other occlusal anomalies present such as posterior crossbite, arch narrowing, crowding or spacing which will require management at the same time as the saggital malocclusion. The development of orthognathic surgical treatment has provided a further option for treatment.

Class II division 1 occlusion will usually show a Class II molar relationship and a Class II cuspid relationship. Buccal segment relationships may be altered or distorted by local factors such as early deciduous loss. In addition the buccal segment may show only a tendency to Class II rather than a full Class II relationship. The angulations of the upper and lower incisors may vary markedly from case to case. The only constant feature of the incisor relationship is the increase in overjet. The angulation of the upper incisors to the Frankfort plane may be upright (vertical), normal or extremely proclined. The angulation of the lower incisors to the mandibular plane may be retroclined, normal or proclined. In mild cases the overjet will be minimally increased while in severe cases it will be extreme. Occasionally the upper and lower incisors will be jointly proclined leading to a bimaxillary protrusion with prominence of the upper and lower lips relative to the E line. Such a case will require retraction of both upper and lower incisors as well as reduction of the overjet and the prominence of the lips. In yet other cases the lower lip to E line may show a substantial retrusion.

The overbite may vary from very deep to open bite. In some cases the overbite will be complete and in others it will be incomplete. The vertical relationship between the upper and lower incisors will be dependent on the functional and static soft tissue relationships as well as the vertical skeletal morphology. Analysis of the anterior openbite problem suggests that there is no directly predictable relationship between overbite and the severity of the vertical skeletal morphology in the majority of cases. (Dung and Smith, 1988). All that may be said is that as the skeletal pattern becomes more vertically elongated, then the overbite will tend to become reduced. The potential for alveolar vertical development to compensate for an excessive vertical skeletal pattern is substantial providing the soft tissues do not override or inhibit this potential. However there is a limit to the degree of alveolar compensation.

Table 1 provides descriptive statistics for a selection of variables measured on three hundred and nine consecutively treated Class II division 1 malocclusions. The mean values do not convey the range of variation between the minimum and maximum values. It is not possible to use Angle's classification alone as an indicator of treatment. The only thing we can say is that the overjet should be corrected – but how?

Variable	Mean	Min	Max	s.d.
SNA	81.0	68.0	94.0	4.1
SNB	76.1	65.0	87.0	3.7
ANB	4.9	-8.0	11.0	2.6
Facial axis angle	89.3	72.0	101.0	4.5
Facial plane angle	87.3	74.0	97.0	3.3
Mandibular plane angle	24.8	6.0	57.0	5.8
Lower face height	43.8	32.0	65.0	5.1
Mx incisor to Frankfort plane	119.5	93.0	149.0	8.5
Md incisor to mandibular plane	95.4	75.0	119.0	7.3
Inter incisal angle	120.3	89.0	148.0	10.1
Md incisor to A Pog (mm)	0.1	-7.0	10.0	2.6
A point convexity (mm)	3.6	-5.0	12.0	2.8
Lower lip to E line (mm)	-0.7	-9.0	18.0	3.7
Overbite (mm)	3.9	-3.0	12.0	2.1
Overjet (mm)	8.6	2.0	17.0	2.9

Table 1: Descriptive statistics for variables measured on 309 consecutive cases of Class II division 1 malocclusion

SOFT TISSUES

Soft tissue patterns vary widely and the question of considerable interest in some cases is whether the soft tissues are the cause or the result of the Class II division 1 malocclusion. As the dental relationships become more abnormal, the overlying soft tissue relationships will deteriorate. In mild cases the patient may be able to achieve a near normal lip seal. In severe cases with a short upper lip the upper incisors may be uncovered. The upper incisors may also lie outside the lower lip. Where the lip morphology is particularly deficient the only anterior seal the patient can achieve on swallowing is between the lingual surfaces of the upper incisors, the tongue and the lower lip with some downward and forward displacement of the mandible. Habitual forward posture of the mandible is seen in some patients. The forward posture of the mandible eliminates the overjet and facilitates a more functional relationship of the lips without so much lip strain. Where the tongue constantly rests and functions over the lower incisor edges in contact with the lower lip the overbite will be incomplete. Usually atypical adaptive swallowing patterns will disappear with treatment as the overjet is reduced and the seal of upper to lower lip becomes easier. As children mature the lengths of the lips increase and

while incompetent lips are seen in the adult, the frequency and severity of incompetence are reduced with age.

Occasionally the clinician is confronted by an endogenous or primary tongue thrust which seems to be an inherited pattern of activity. It is commonly associated with an anterior lisp which can be detected by carefully watching the patient talk or asking the patient to recite a phrase such as "six sizzling sausages". In some cases a similar anomalous pattern will be observed in a sibling or parent which raises the question of whether the pattern is truly inherited or familial. The tongue is visible between the incisors at rest and during speech and swallowing. There is usually an anterior openbite tendency. The picture becomes even more complicated if the child is also a digit sucker and it may be very difficult to unravel the etiology in some of these cases. However, the combination of lisp, tongue thrust with circumoral contraction of both upper and lower lips, forward tongue resting posture and openbite tendency should be assessed cautiously before treatment because partial or complete relapse is common.

These extremes of variation in incisor relationships and soft tissue patterns make it very difficult to determine the true etiology of many Class II division 1 malocclusions particularly where the underlying skeletal morphology is also abnormal. These same factors may make it difficult to predict the stability of the treated result even where undue expansion or proclination has not been undertaken. In the more severe skeletal problem cases the treatment plan can be nothing more than the best available compromise. Where that compromise is unacceptable, orthognathic surgery may offer the most practical solution. Occasionally no treatment may be the best option.

SKELETAL PATTERN

The skeletal pattern in cases of Class II division 1 malocclusion is subject to wide variation from mesofacial to brachyfacial or dolichofacial. The severity of the skeletal antero-posterior discrepancy between upper and lower jaws may vary from near normal to severe. The brachyfacial type is expected to grow with more horizontal emphasis while the dolichofacial type is expected to grow with more vertical emphasis. Treatment planning must be cognisant of the expected growth pattern of the skeletal type even though the accuracy of growth prediction may be flawed. In cases tending to a brachyfacial pattern, the expected horizontal growth emphasis will provide considerable advantage to the effects of a functional appliance leading to a more predictable reduction of the Class II malocclusion. In dolichofacial types the expected vertical growth emphasis will not complement functional appliance therapy. The more dolichofacial the case the less confident the operator would be with a functional appliance.

A brachyfacial Class II division 1 malocclusion may exhibit the following features:

- Below average mandibular plane angle
- Below average lower face height

- Increased facial axis angle
- Deep overbite
- Square mandibular morphology
- Horizontal growth emphasis
- Lower lip behind the E line, perhaps with a lip trap

These features may be present in various combinations however there is no mistaking the severely brachyfacial type. The facial musculature also becomes more distinctive with full broad masseter muscles. Research suggests that the vertical muscular force exerted in these cases is increased and more directly at right angles to the occlusal plane and lower border of the mandible giving greater mechanical efficiency. This is one explanation for the difficulty of bite opening in some cases. As the patient ages overbite control becomes more difficult. Earlier treatment is an advantage and combined with the general tendency to non-extraction treatment, the commencement of treatment before complete eruption of the permanent buccal teeth may make treatment easier for both the patient and operator. However, occasionally the degree of crowding warrants extractions.

The dolichofacial Class II division 1 malocclusion may exhibit the following features:

- Above average mandibular plane angle
- Increased lower face height
- Decreased facial axis angle
- Tendency to reduced overbite
- Strained incompetent lips
- Adaptive swallowing pattern
- Vertical growth emphasis
- Tendency to a convex profile.

These features may occur in various combinations and degrees of severity. As the individual becomes more obviously dolichofacial, the clinician will strive to avoid biomechanics which will tend to open the bite or cause a deterioration of the profile. Extractions in the upper arch only may provide an acceptable compromise where the extrusive effects of headgear or inter-maxillary elastics are to be avoided. But the objectives of treatment will again be dictated by the horizontal positions of the upper and lower skeletal bases and modified by the vertical skeletal pattern. Soft tissue function will further influence objectives.

Ultimately, in both brachyfacial and dolichofacial types, the horizontal and vertical abnormalities may become too severe for orthodontic correction and surgery will be required. Surgery possesses the further considerable advantage of allowing correction simultaneously in the horizontal and vertical dimensions – allowing correction of the retrognathic mandible and impaction of the maxilla in cases of vertical maxillary excess (VME). Functional appliances may be used in the less severe dolichofacial types but their morphology and an expected vertical growth emphasis, make clinicians cautious.

HEADGEAR

Depending on the antero-posterior position of the maxilla the operator will consider the use of headgear to move the upper dento-alveolar complex distally. Where the A point convexity is below average or even negative the operator may seek to avoid the retardation effect of headgear. On the other hand where the A point convexity is increased the operator will take advantage of any consequential effect of the headgear in reducing the forward development of the alveolus. As a compromise the headgear force may be reduced to support anchorage rather than to drive the upper arch distally. Similarly where the OPG suggests crowding and stacking of upper molars in the tuberosity region, distal driving of upper molars may be undesirable, causing more pronounced distal angulation of the upper molars and the need to consider extractions to overcome this problem.

The design of the headgear must be tailored to the skeletal pattern. A cervical headgear will pull below the centre of resistance of the first permanent molar causing both distal and extrusive forces. Whether this extrusive force overcomes the muscles of mastication depends on the magnitude of the force, the skeletal type and the hours of wear. The effects of a cervical headgear are more likely to be acceptable in the brachyfacial type rather than the dolichofacial type. As the possibility of extrusion becomes less acceptable to the clinician in setting treatment objectives, then the headgear design should be varied to either a straight pull or high pull type with forces through or above the centre of resistance of the first permanent molar.

TREATMENT OPTIONS

The essence of treatment in Class II division 1 malocclusion is to reduce the overjet and to manage the saggital buccal segment relationships. Reduction of the overjet may be accomplished by a combination of upper incisor retraction and, rarely, lower incisor protraction. The teeth may be tipped or moved bodily. The decision to be made is conceptually simple. How much do we move the upper incisors back and should we tip the teeth or move them bodily? What will be the resultant interincisal angle? Management of the saggital buccal segment relationships is also conceptually simple – should they be finished in a Class I or Class II molar relationship ? If no teeth are extracted, the molars and canines should be finished in a Class I relationship. If a bicuspid is extracted in each quadrant of the upper and lower arches, then the molars and canines should be finished in a Class I relationship. If a bicuspid is extracted on each side of the upper arch only, then the molars should be finished in a Class II relationship and the canines finished in a Class I relationship (Fig. 1).

Of course the practicalities of the process are a good deal more complex and modifying factors include the amount of overbite or openbite, the amount of crowding, the soft tissue pattern and the profile outline. In many cases the profile will be considerably enhanced by treatment. In others it may be very difficult to

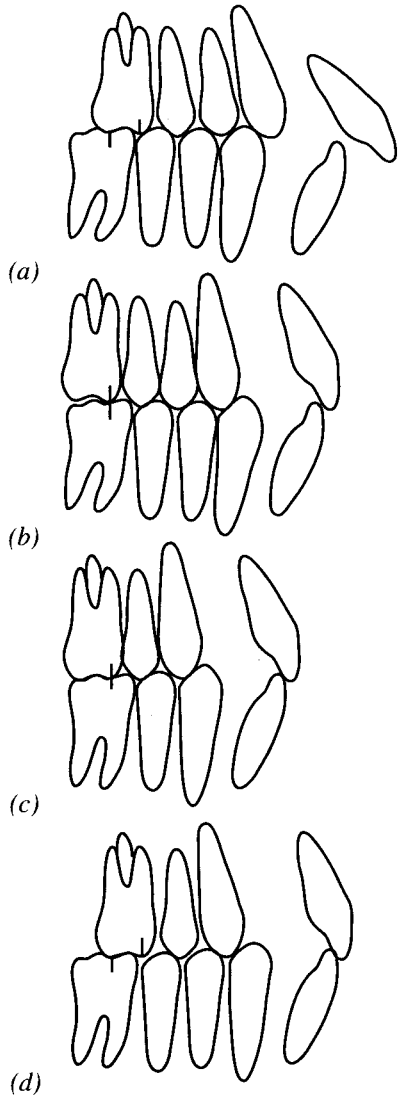


Fig. 1: Buccal segment management in Class II division 1 malocclusion (a) pretreatment Class II arrangement (b) nonextraction treatment with correction of the buccal segments to Class I before correction of the overjet (c) extraction of a bicuspid in all four quadrants requiring correction of the buccal segments to Class I before correction of the overjet (d) upper arch bicuspid extraction only with correction of the canine relation to Class I before correction of the overjet leaving the molars in Class II relation.

obtain dental correction and to prevent deterioration of the profile. Analysis of the dental, skeletal and soft tissue elements must be integrated to set treatment objectives.

Dental Factors

Proclined, normal or upright upper incisors

Proclined, normal or retroclined lower incisors

Increased, normal or reduced overbite

Crowded, normal or spaced upper arch
Crowded, normal or spaced lower arch
Crossbite

Skeletal Factors

Protrusive, normal or retrusive maxilla
Protrusive (rare), normal or retrusive mandible
Increased, normal or reduced skeletal height

Soft Tissue Factors

Incompetent lip morphology
Lip trap
Tongue thrust
Digit sucking habit

In general terms the pretreatment antero-posterior position of the lower incisors acts as the template for correction of the dentition. It is unwise to alter the pretreatment positions of the lower incisors in the majority of cases. Exceptions may be allowed where there is a major change in the functional environment associated with treatment. For example where the lower lip lies behind the upper incisors before treatment causing retroclination of the lower incisors in association with a marked thumb sucking habit, it may be possible to procline the lower incisors a little.

Lower arch extractions have been shown on average to result in some retroclination of the lower incisors – about four degrees (Sims and Springate, 1995). Where the characteristics of the case suggest that any retroclination of the lower incisors is undesirable, lower extractions should be avoided. The only alternatives are upper arch extraction or retraction of the whole upper arch without extractions using a headgear or perhaps a functional appliance. The possible disadvantage of a functional appliance is that it will tend to procline the lower incisors. Thus the operator is constantly trying to balance the requirements of overjet reduction, lower arch space requirements, incisor stability and acceptable profile outcomes.

SETTING OBJECTIVES

Figs. 2 and 3 illustrate some of the variation in Class II division 1 morphology which may occur. The four cases constitute a small fraction of the possible combinations. Fig. 2(a) is a Class II division 1 case with a near mesofacial pattern. The mandibular plane angle is 24 degrees and the lower face height is reduced slightly at 40 degrees. The upper incisors are slightly proclined at 122 degrees and the lower incisors are slightly proclined at 100 degrees. A point to nasion vertical is 0 mm and confirms the position of A point as suggested by the SNA value of 78

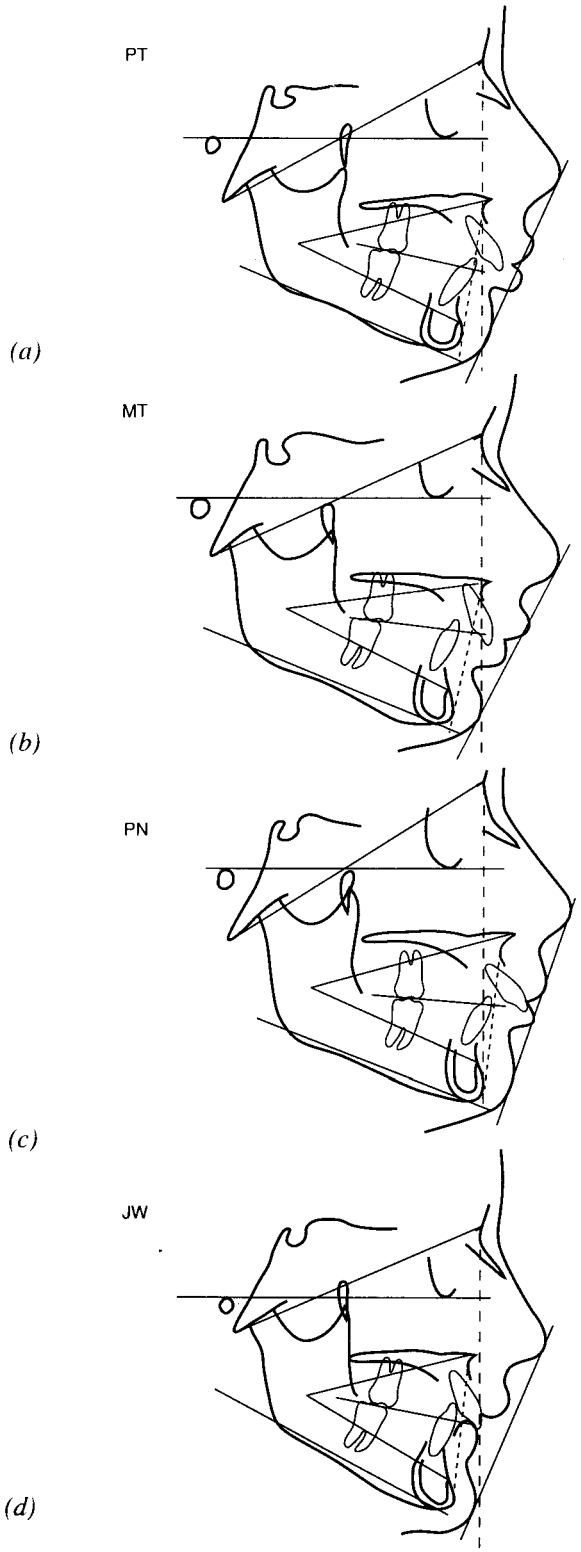


Fig. 2: (a,b,c,d) Tracings of four contrasting Class II division 1 morphologies. All tracings are aligned on the nasion vertical line. Note the variation in A point position, pogonion position, incisor positions and angulations and lip protuberance.

(Case PT)

SNA	78°	MPA	24°	APt Nav	0 mm	MxIFHP	122°
SNB	73°	F Angle	87°	PoNav	-8 mm	MdIMP	100°
ANB	5°	F Axis	88°	P/AFHt(.75)	0.63	IIA	114°
Wits	2 mm	LFHt	40°	LLEL	+3 mm	MdIAPo	-1 mm

(a)

(Case MT)

SNA	80°	MPA	23°	APt Nav	0 mm	MxIFHP	112°
SNB	76°	F Angle	84°	PoNav	-11 mm	MdIMP	93°
ANB	4°	F Axis	95°	P/AFHt(.75)	0.68	IIA	133°
Wits	10 mm	LFHt	35°	LLEL	-2 mm	MdIAPo	-7 mm

(b)

(Case PN)

SNA	82°	MPA	22°	APt Nav	+9 mm	MxIFHP	130°
SNB	74°	F Angle	90°	PoNav	-1 mm	MdIMP	100°
ANB	8°	F Axis	90°	P/AFHt(.75)	0.63	IIA	109°
Wits	7 mm	LFHt	39°	LLEL	-1 mm	MdIAPo	-2 mm

(c)

(Case JW)

SNA	83°	MPA	28°	APt Nav	-5 mm	MxIFHP	116°
SNB	78°	F Angle	85°	PoNav	-10 mm	MdIMP	83°
ANB	5°	F Axis	93°	P/AFHt(.75)	0.67	IIA	133°
Wits	2 mm	LFHt	44°	LLEL	-10 mm	MdIAPo	-4 mm

(d)

Fig. 3: (a,b,c,d) Cephalometric values for the cases represented by the tracings in Fig. 2.

degrees. The position of pogonion to nasion vertical is retruded at -8 mm and SNB is only 73 degrees. The lower incisor is slightly behind the APo line at -1 mm. The lips are slightly protrusive. The composite picture suggests a malocclusion due to upper incisor proclination and slight mandibular retrusion.

The main emphasis of treatment should be coordination of the upper and lower arches without any further proclination of the lower incisors. If headgear is used it should be very light because A point is not protrusive. Alternatively, if the lower arch alignment is good, extractions in the upper arch only might be considered. The upper incisor angulations are slightly proclined and may be retracted with controlled tipping at the same time correcting the overbite. While a functional appliance might

be considered, the reciprocal effect would tip the lower incisors forward and be likely to cause post-treatment instability and crowding.

Fig. 2(b) shows a brachyfacial type with near normal angulations of both the upper and lower incisors and slightly protuberant upper lip and evidence of a lower lip trap. The midface is not protrusive relative to the nasion vertical and this is confirmed by the SNA value of 80 degrees. The mandibular symphysis on the other hand is very retrusive to the nasion vertical line and the lower incisor edge lies well behind the APo line at -7 mm. Extraction in the lower arch will lead to uprighting of the lower incisors with an exageration of the retrusive position of the mandible. Thus if there was a need to extract in the lower arch this might be expected to be a very testing case to treat orthodontically. An alternative might be lower extractions to be followed by surgery.

The next case in Fig. 2(c) is tending to brachyfacial. The lower lip is trapped behind the upper incisors. The upper incisor angulation is proclined. The maxilla is protrusive to the nasion perpendicular although SNA is normal at 82 degrees. The mandible is normal to the nasion perpendicular line even though SNB is 76 degrees. Headgear might be indicated. The lower incisor lies just behind the APo line due to the protrusion of A point. If there is substantial crowding in the lower arch, extractions might be contemplated although care would be required to prevent undue retrusion of the lower incisors.

The final case in Fig. 2(d) shows both the maxilla and mandible to be retrusive to the nasion perpendicular line although SNA is normal at 83 degrees. However SNB at 78 degrees reflects the retrusion of the symphysis to the nasion vertical line at -10 mm. The lower incisors are very retroclined at 83 degrees and lie behind the APo line at -4 mm. The lower lip lies behind the upper incisors. The lips are very retrusive to the E line. The general morphology of the case suggests that lower arch extractions should be avoided.

These four cases demonstrate the variations in retrusion and protrusion of the upper and lower skeletal bases associated with Class II division 1 malocclusions. Treatment objectives are designed to camouflage any skeletal discrepancy, improve or maintain the profile appearance, reduce the overjet and align the teeth in both arches so that they remain stable after correction. Not infrequently, not all objectives can be met by orthodontic treatment. The inexperienced operator is strongly encouraged to visualise the incisor angulations before and after reduction of the overjet. If only uncontrolled tipping movements are possible, this will limit the amount of correction possible. If controlled tipping or torque is possible then the limits of orthodontic correction are extended to medium severity cases. Severe anomalies require orthognathic surgery.

If the skeletal discrepancy is minimal with slight protrusion of the upper skeletal base and teeth then simple removable appliance treatment with upper arch extractions only is a reasonable option, providing the lower arch and the post-treatment inter-

incisor angulations are acceptable. The buccal segments will remain in a Class II relationship. As the crowding in the lower arch increases, lower extractions become necessary and correction of the buccal segments to a Class I molar relationship is required. Buccal segment correction cannot be achieved by removable appliances. Fixed appliances, perhaps with a headgear, will be required. The use of functional appliances is more strongly recommended where the facial type is mesofacial or brachyfacial and the upper and lower arch alignments are acceptable without a tendency to crowding. Ideally the lower incisors should not be proclined such that long term stability is compromised.

Full fixed appliance treatment with extractions in both upper and lower arches is difficult for the inexperienced operator to manage in Class II division 1 malocclusions. This form of treatment requires simultaneous correction of the Class II relation, overbite control, tooth alignment and space closure with root parallelism. The complexities of force control are very involved. While it may seem simple to place appliances with fully pre-torqued attachments which require little understanding of the inter-relationships of forces, no system of fixed appliances is capable of obviating the effects of arch wires which are bitten out or otherwise bent. Neither is patient compliance related to the type of appliance used.

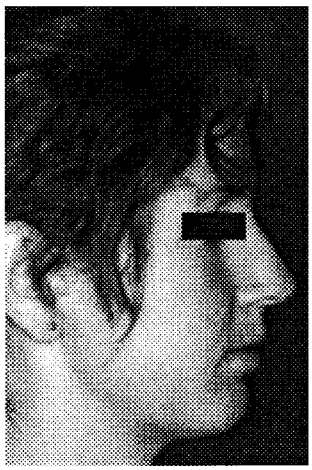
CASE PRESENTATIONS

The first case (Figs. 4,5 – GA) has a slightly atypical Class II division 1 malocclusion with one upper central incisor being proclined and the other being retroclined, reminiscent of a Class II division 2 malocclusion. The proclined incisor protrudes into the lower lip. The upper arch is very crowded. Both upper lateral incisors are below average widths. The buccal segment relationship is Class II. The upper right cuspid is upright and the upper left cuspid is distally inclined. The lower arch is slightly crowded and the lower first permanent molars have been previously extracted with some tipping of the lower second molars. Third molars are present.

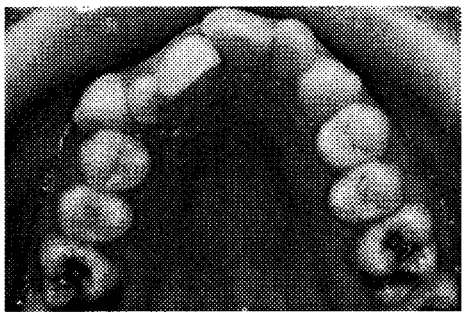
Cephalometric analysis revealed that SNA and SNB were both less than average with an ANB of 4 degrees and a Wits value of 4 mm. There was a mild dolichofacial pattern with a mandibular plane angle of 29 degrees and a lower facial height of 50 degrees. The facial axis angle was 84 degrees and the facial plane angle was also 86 degrees – both below normal and consistent with the dolichofacial type. The A point position was retrusive to the nasion vertical line at -4 mm. The soft tissues were within normal limits although there was lip strain on closure. The upper incisors were slightly proclined and the lower incisors slightly retroclined. Given the dolichofacial pattern it was felt undesirable to risk causing mandibular posterior rotation by trying to reduce the molar relationship to Class 1. The distal angulations of the upper canines also required extra anchorage in their angular correction as uprighting would tend to throw the crowns forward. Uprighting of the lower molars would tend to distalise their crowns even further. This is a maximum anchorage case.

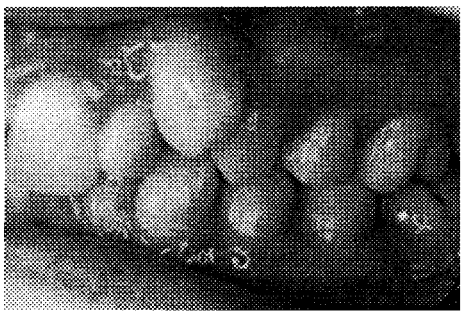
(Case GA)

SNA	79°	MPA	29°	APt Nav	-4 mm	MxIFHP	115°
SNB	75°	F Angle	86°	PoNav	-9 mm	MdIMP	85°
ANB	4°	F Axis	84°	P/AFHt(.75)	0.65	IIA	132°
Wits	4 mm	LFHt	50°	LLEL	-2 mm	MdIAPo	-2 mm

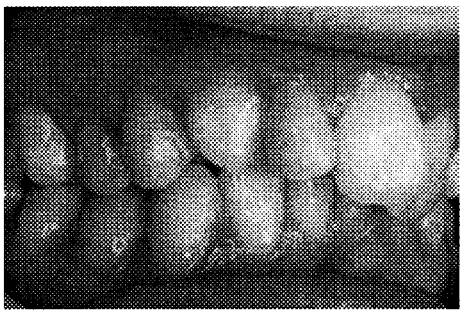


(a)

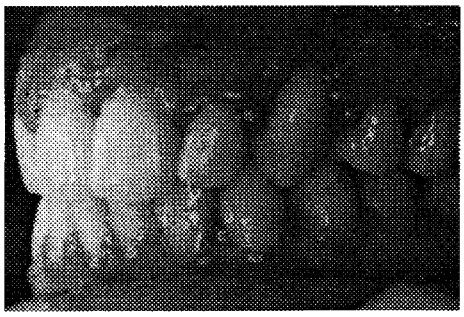




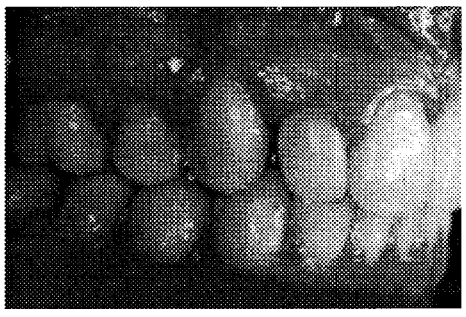
(b)



(c)



(d)



(e)

Fig. 4: (a-c) Class II malocclusion in an adult – pretreatment (d,e) at deband.

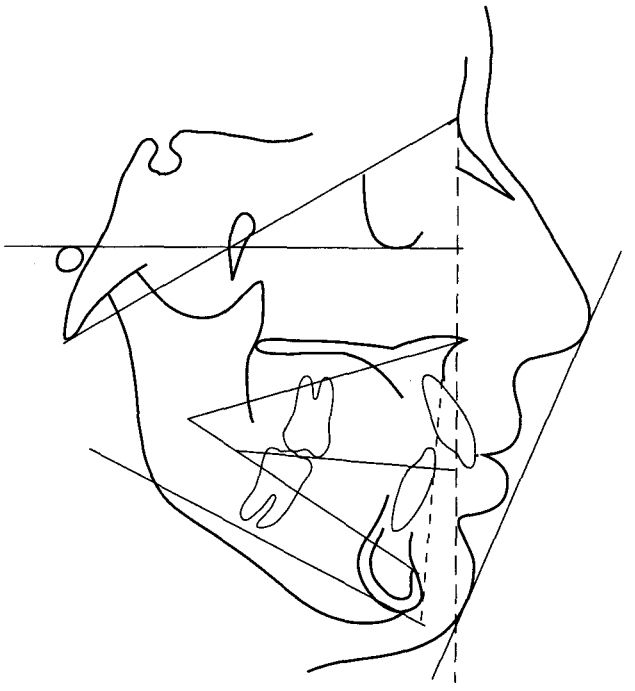


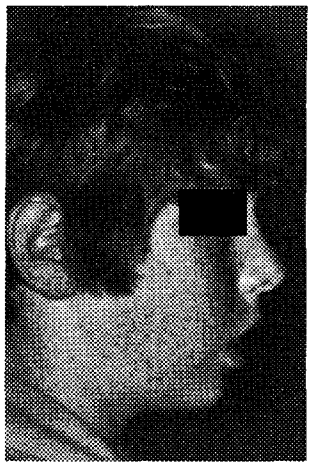
Fig. 5: Pre-treatment tracing of same adult patient in Fig. 4.

To minimise anchorage strain the upper first premolars were extracted along with the upper third molars to balance the early loss of the lower first permanent molars. There would be no attempt to correct the molar relationships to Class I. Treatment required full arch banding/bonding. Case notes show that the patient was an excellent cooperator. Treatment time was 36 months followed by retention. Small spaces distal to the upper lateral incisors are the result of the reduced widths of these teeth. The final photographs show that the treatment objectives have been met with correction of the incisors and satisfactory uprighting of the upper canines and lower molars.

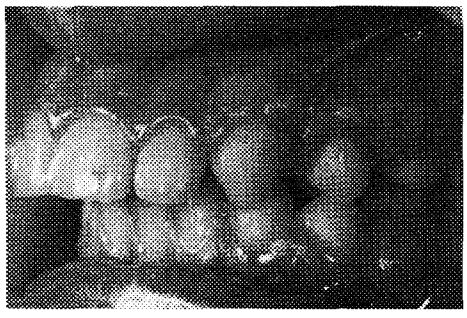
The next case (Figs. 6,7 – LL) is dolichofacial Class II division 1 type. The left molar relationship is cusp to cusp although the cuspid relationship is full Class II. The right buccal segment is cusp-to-cusp but the cuspid relationship is Class II. There is considerable occlusal wear consistent with bruxing and the first molars cusps in particular have been worn flat. Cephalometric analysis reveals a dolichofacial pattern with a facial axis angle of 83 degrees and a facial plane angle of 80 degrees. The mandibular symphysis is retrusive to the nasion vertical (-19mm) while the maxilla to the nasion vertical is at -2mm. SNA and SNB are 79 and 71 degrees respectively. The upper incisors are proclined at 116 degrees to the Frankfort plane while the lower incisors are at 94 degrees to the mandibular plane. The lips are protuberant but incompetent and there was lip strain on closure. The profile is convex because of the retrusive mandible. Anterior face height is increased relative to posterior face height.

(Case LL)

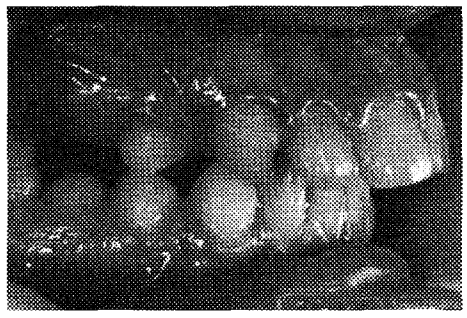
SNA	79°	MPA	36°	APt Nav	-2 mm	MxIFHP	116°
SNB	71°	F Angle	80°	PoNav	-19 mm	MdIMP	94°
ANB	8°	F Axis	83°	P/AFHt(.75)	0.58	IIA	115°
Wits	4 mm	LFHt	49°	LLEL	+4 mm	MdIAPo	+1 mm



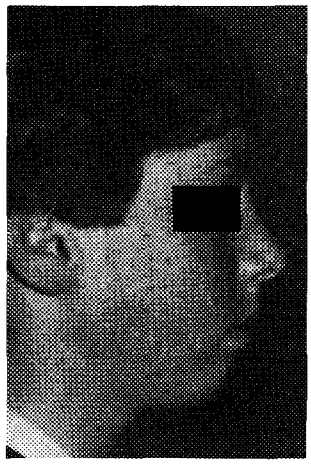
(a)



(b)



(c)



(d)

Fig. 6: (a) Pre-treatment profile of dolichofacial Class II division 1 patient (b,c) pre-treatment occlusion (d) post-treatment profile with extraction of upper first bicuspids only.

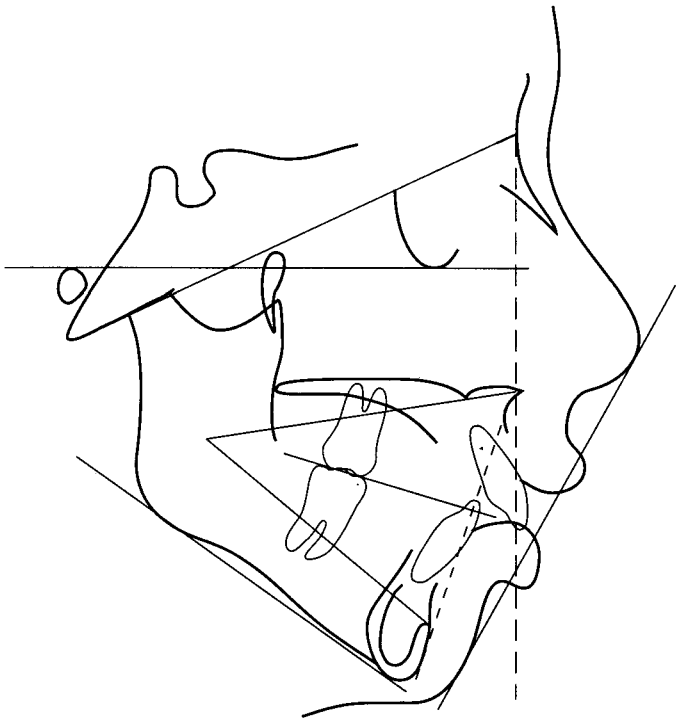


Fig. 7: Pre-treatment tracing of dolichofacial patient shown in Fig. 6.

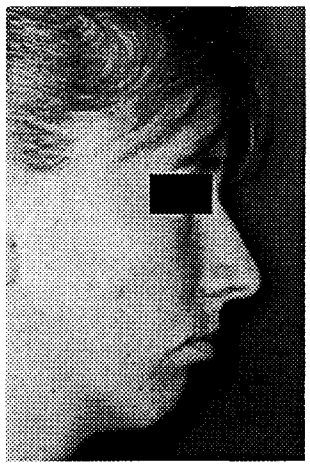
The facial pattern is dolichofacial and suggests the need for caution in view of the incomplete overbite and the significant occlusal wear. Orthognathic correction was not an option. In view of the full lips it was decided therefore to extract the upper first bicuspids as a compromise and to retract the upper incisors minimising both treatment time and the use of elastics. The post-treatment profile is acceptable.

The next case (Figs. 8,9,10 – KG) is also a dolichofacial Class II division 1 case with a convex profile and strained lips on closure. SNA and SNB are 77 degrees and 71 degrees respectively. The facial axis and facial angle are 80 and 83 degrees respectively and the mandibular plane angle is increased at 34 degrees. Lower face height is 48 degrees. The maxilla is slightly retrusive to the nasion vertical while the symphysis is very retrusive at -15 mm to the nasion vertical line. The posterior to anterior face height ratio is decreased. The Wits value is 7 mm. Both left and right molar relationships are Class II. The lower arch is very crowded. The upper incisor angle to Frankfort plane is near normal at 114 degrees. The lower incisor to mandibular plane angle is 91 degrees. The upper right canine had been previously extracted because it was in a high buccal position. Clinical examination revealed a wide smile with excessive exposure of the maxillary alveolus and gingival tissues.

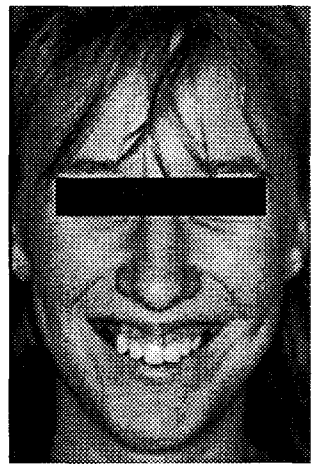
Treatment involved extraction of the left upper first bicuspid and both lower first bicuspids with alignment, space closure and arch coordination as well as minimal

(Case KG)

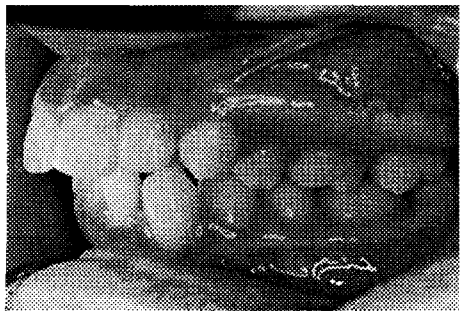
SNA	77°	MPA	34°	APt Nav	-2 mm	MxIFHP	114°
SNB	71°	F Angle	83°	PoNav	-15 mm	MdlMP	91°
ANB	6°	F Axis	80°	P/AFHt(.75)	0.55	IIA	120°
Wits	7 mm	LFHt	48°	LLEL	+1 mm	MdlAPo	+1 mm



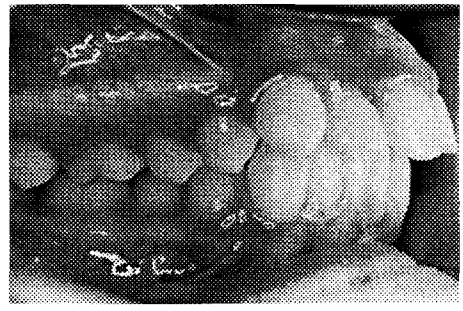
(a)



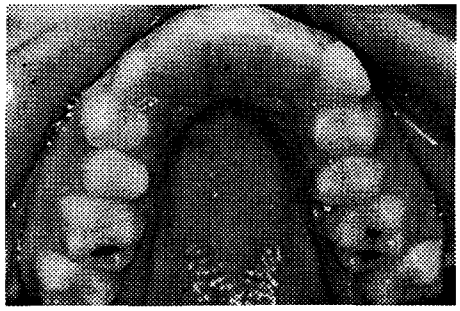
(b)



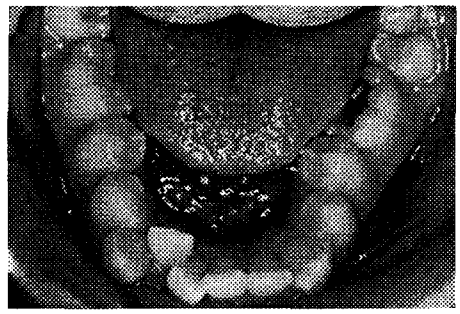
(c)



(d)



(e)



(f)

Fig. 8: (a-f) Pre-treatment records of a severe Class II division 1 with crowding and prior loss of the upper right canine.

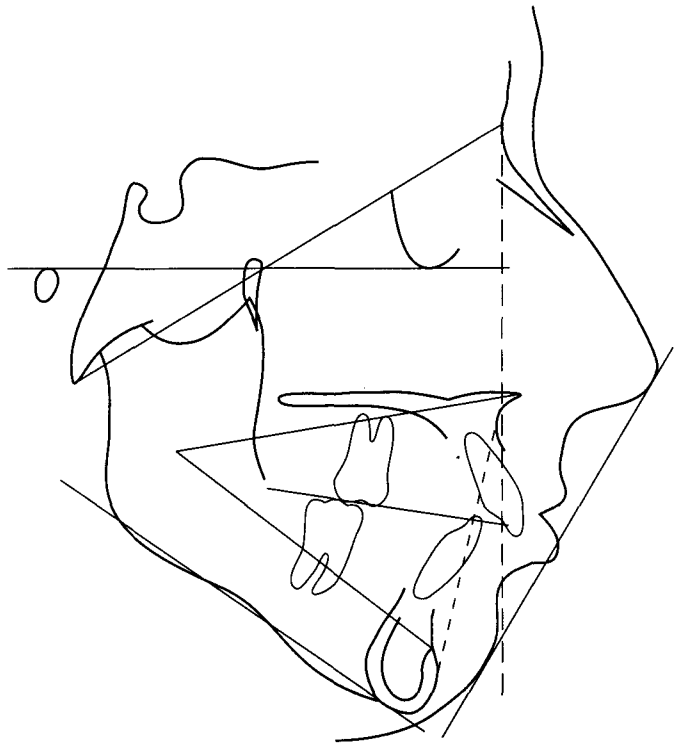
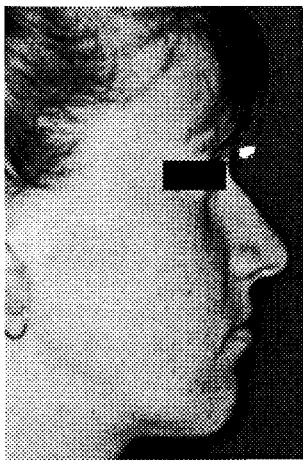


Fig. 9: Pre-treatment tracing of same patient shown in Fig. 8.

decompensation of the lower incisors. This was followed by orthognathic correction of the saggital relationship and impaction of the maxilla to reduce the vertical excess, at the same time improving the profile line. Post-treatment results show good arch alignment with substantial improvement in the profile and reduced lip strain (Fig. 10). On smiling there is now little exposure of the maxillary alveolus and soft tissues. In conformity with the extractions in the upper and lower arches, the buccal segment relationships are now Class I.

The final case report (Figs. 11,12 - SM) shows a Class II division 1 brachyfacial pattern without a marked skeletal abnormality although there is a tendency to mid-face protrusion. The upper incisors are very proclined at 131 degrees while the lower incisors are proclined at 103 degrees although lying behind the A Pog line at -2.5 mm. The posterior to anterior face height ratio is normal and in contrast to several of the previous cases. The brachyfacial pattern suggests that the growth response during treatment will be favourably horizontal.

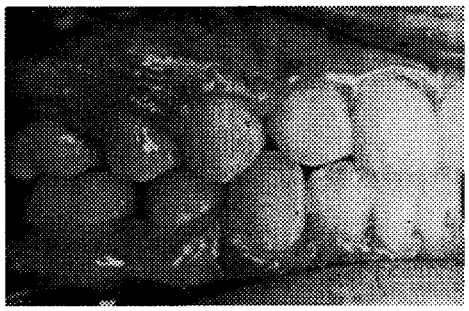
The decision was made to treat the case with headgear to reduce the Class II buccal segment relationships to Class 1, to be followed by correction of the incisors. The use of inter-arch elastic traction was to be minimised to avoid further proclination of the lower incisors. The post-treatment records show a significant improvement in the occlusion. Interestingly the mid-face relative protrusion has persisted in spite



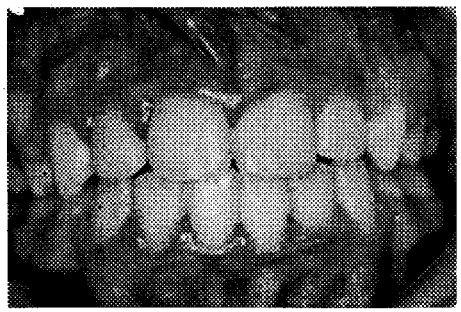
(a)



(b)



(c)

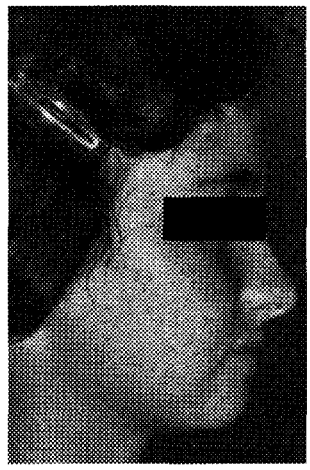


(d)

Fig. 10: (a-d) Post-treatment records at deband of case shown in Fig. 8.

(Case SM)

SNA	86°	MPA	16°	APt Nav	+3 mm	MxIFHP	131°
SNB	80°	F Angle	88°	PoNav	-4 mm	MdlMP	103°
ANB	6°	F Axis	92°	P/AFHt(.75)	0.76	IIA	110°
Wits	4 mm	LFHt	35°	LLEL	-5 mm	MdlAPo	-2.5 mm



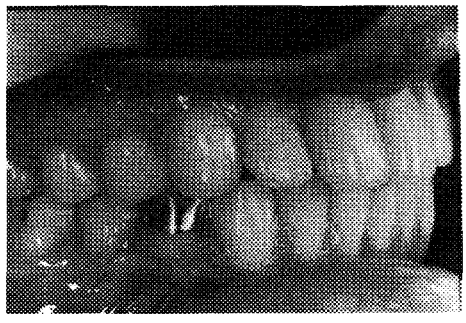
(a)



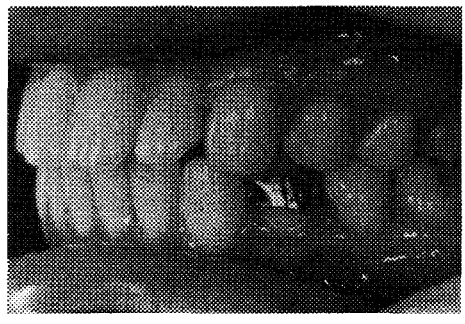
(b)



(c)



(d)



(e)

Fig. 11: Pre-treatment records of a brachyfacial Class II division 1 malocclusion (d,e) post-treatment records.

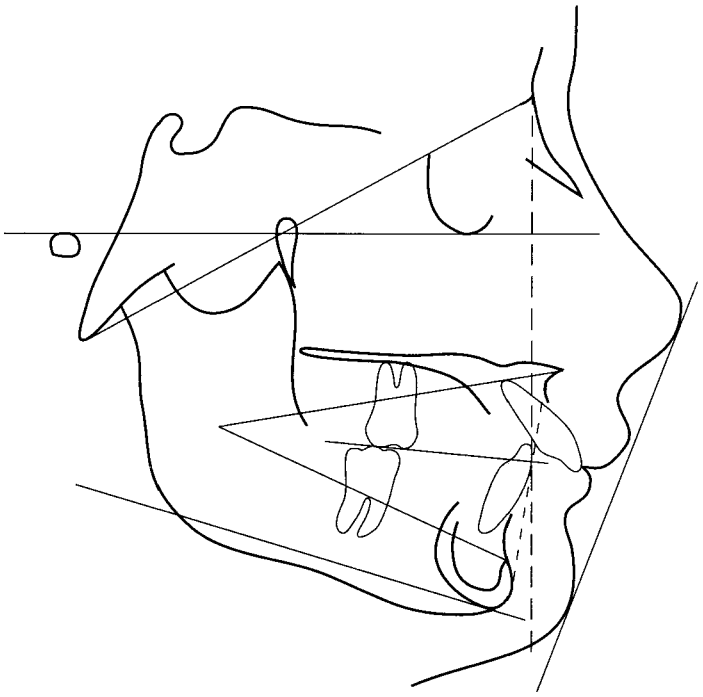
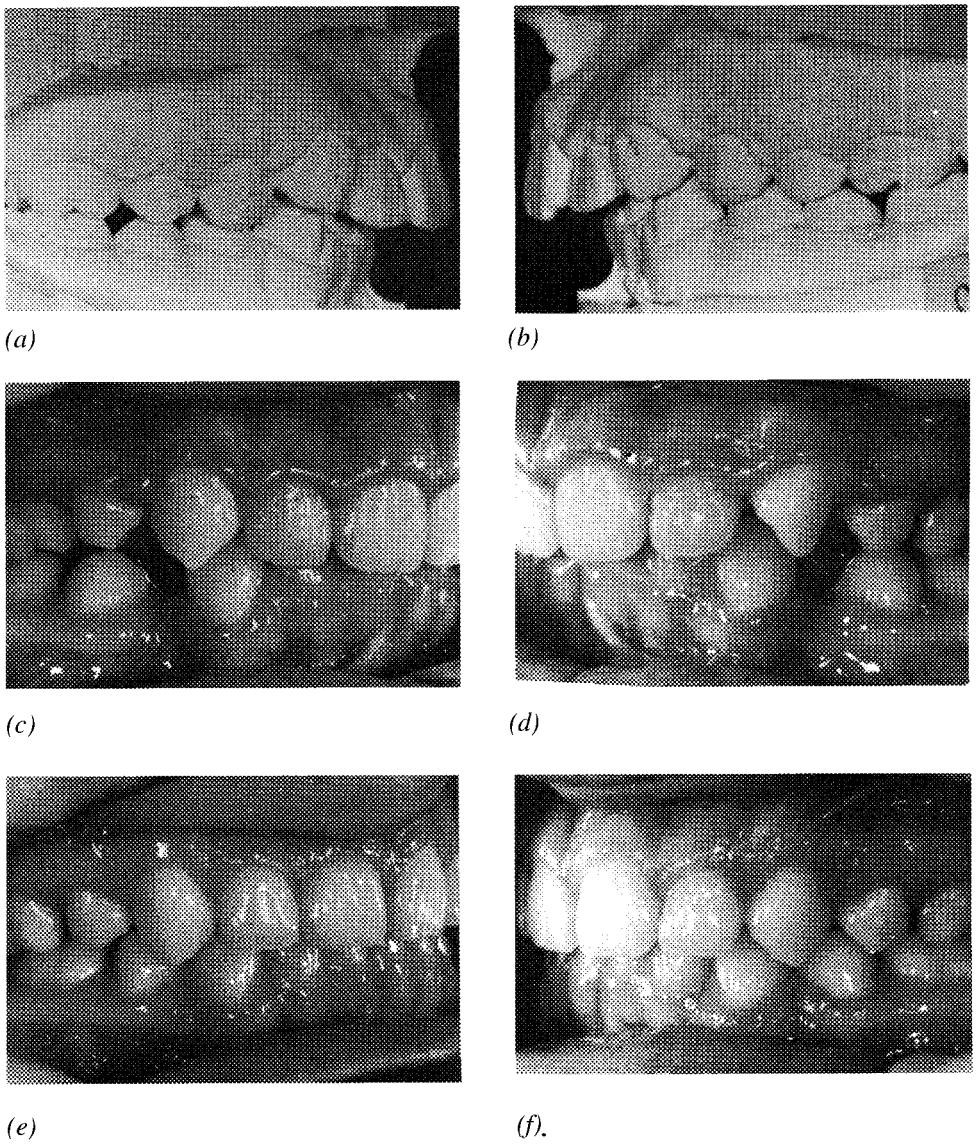


Fig. 12: Pre-treatment tracing of same patient shown in Fig. 11.

of the correction. Extractions in the upper arch only may have been a reasonable alternative treatment plan in this case.

Fig. 13 shows the records of a Class II division 1 malocclusion treated with extraction of four first bicuspids. An attempt was made to treat the case with removable appliances resulting in some reduction of the overjet but without the necessary correction of the buccal segments to Class 1. Further treatment was continued with fixed appliances to move the buccal segments to Class 1 and to correct the incisor relationships. Treatment of Class II division 1 malocclusions requiring extractions in both upper and lower arches will usually require fixed appliances to achieve a satisfactory result.

Fig. 14 shows the records of a Class II division 1 case treated only with removable appliances. No attempt was made to correct the buccal segment relationships. The lower arch alignment was good and it was decided to extract upper first bicuspids only leaving the molars in a Class II relationship. The first step in treatment was retraction of the canines to a Class 1 relationship. This was followed by retraction of the four incisors and space closure. The final result is quite acceptable.

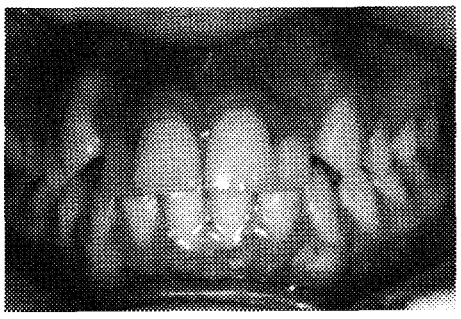


(a) *(b)*

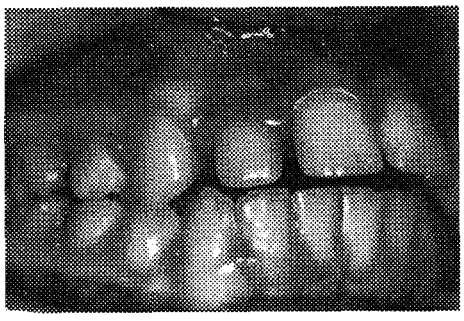
(c) *(d)*

(e) *(f).*

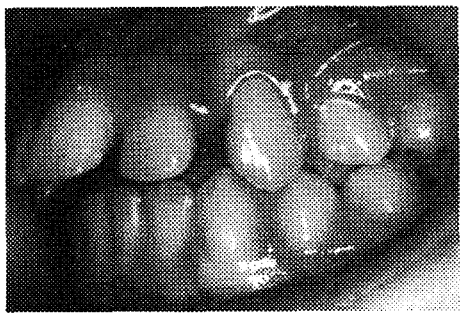
Fig. 13: (a) Pretreatment models of Class II division I malocclusion (b) after extraction of first bicuspids (c) after correction of buccal segment relations to Class I.



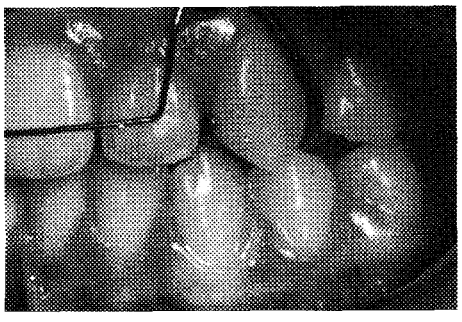
(a)



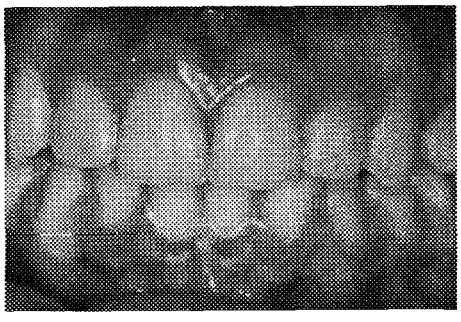
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(c)



(d)



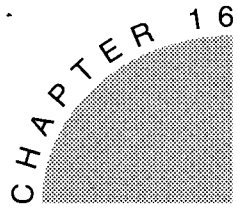
(e)

Fig. 14: (a) Pretreatment view of a Class II division 1 malocclusion treated with removable appliances only (b,c) after retraction of the canines with palatal springs and anterior bite opening with a bite plate (d) retraction of incisors with a Roberts retractor (e) after complete space closure with a labial bow.

References

Dung D J and Smith R J (1988): Cephalometric and clinical diagnoses of open bite tendency. Amer J Orthod Dentofac Ortho 94 : 484-90.

Sims A P and Springate S D (1995): Stability of the lower labial segment following orthodontic treatment - a comparison of treatment with Andresen and Begg appliances. Brit J Orthod 22: 13-21.



Class II Division 2 Malocclusion

Class II division 2 malocclusion was defined by Angle as any malocclusion with a Class II molar relationship greater than half a cusp displacement and retruded upper incisors. While not part of Angle's original description of division 2, a characteristic arrangement of the upper incisor segment is usually described with the upper central incisors being retroclined while the upper lateral incisors are slightly proclined and mesially inclined over the central incisors. The overbite is deep to very deep. In fact it may be very difficult on occasions to classify a case as either division 1 or division 2 because the upper incisors may be very upright but the overjet is increased. Furthermore these cases may not show the classical proclined and mesially inclined upper lateral incisors. This has led some authors to describe a further class designated as Class II indefinite. This is not part of Angle's classification but does provide an extra class which is neither division 1 or division 2. However this type of solution defeats the purpose of Angle's classification but underlines its shortcomings.

Variable	Mean	Min	Max	s.d.
SNA	80.9	75.0	87.0	3.7
SNB	75.9	70.0	83.0	3.6
ANB	5.0	2.0	8.0	1.5
Facial axis angle	90.3	84.0	96.0	3.0
Facial plane angle	86.8	77.0	91.0	3.7
Mandibular plane angle	22.7	11.0	33.0	5.5
Lower face height	41.2	34.0	49.0	4.4
Mx incisor to Frankfort plane	98.6	77.0	118.0	9.4
Md incisor to mandibular plane	90.3	82.0	101.0	5.7
Inter incisal angle	148.8	123.0	169.0	12.6
Md incisor to A Pog (mm)	-3.3	-8.0	2.0	3.0
A point convexity (mm)	3.3	-1.0	7.0	2.1
Lower lip to E line (mm)	-3.1	-7.0	2.0	3.0
Overbite (mm)	7.3	3.0	12.0	2.0
Overjet (mm)	3.2	1.0	7.0	1.4

Table 1: Descriptive statistics for variables measured on 26 consecutive cases of Class II division 2 malocclusion.

Table 1 provides descriptive statistics for a selection of variables measured on twenty six consecutively treated Class II division 2 malocclusions. The size of the sample is indicative of the lower prevalence of this type of malocclusion. While the sample size is relatively small (although statistically acceptable), in comparison with the

Class II division 1 sample there is relatively less variation in the ranges of variables describing skeletal structures. This is seen for SNA and SNB where the maximum and minimum values are less extreme. Similarly, the facial axis, facial plane and mandibular plane angles show smaller ranges and the means suggest a greater tendency to the brachyfacial pattern. On the other hand the mean for the inter-incisal angle (148.8 degrees) is significantly greater than the mean for the Class II division 1 group (120.3 degrees) and the relation of the lower lip to E line is usually retruded on average (-3.1 mm). These statistics tend to confirm the clinical impression of a more homogeneous group but there is still a great deal of variation between individuals. Again, treatment planning must be an integrated process utilising as much information as possible rather than an assessment from a set of models only.

SOFT TISSUES

The range of profiles seen in Class II division 2 malocclusions is not as wide as seen in Class II division 1 types. The lips generally give the impression of over-control of the upper incisors and the lip line tends to be high on the central incisors although in the more severe cases the upper lateral incisors may protrude into the lower lip or even slightly outside it. As the skeletal pattern becomes more retrognathic and the inter-incisal angle increases, the lower lip also becomes more retrusive and will often show a deep supramental groove. The classical convex profile is rarely seen in the division 2 type. In some cases there is a markedly square gonial angle with prominent masseter muscles. The skeletal type tends to be markedly brachyfacial in these cases with low facial height angle and low mandibular plane angle. There is some evidence to suggest that the maximum bite force in these individuals is above normal and it is further suggested that the vertical occlusal development is restricted leading to a deep overbite. Overbite control in the adult patient may be particularly difficult and even in the adolescent patient may be a testing treatment objective. For this reason, amongst others, extractions are usually avoided and treatment at the optimum stage of dental development is recommended.

SKELETAL PATTERN

The occlusion in Class II division 2 cases may vary from a full Class II with very deep overbite to a partial Class II buccal occlusion with a small increase in overbite and minor re-arrangement of the lateral incisors. In fact some of the milder forms of Class II division 2 malocclusion may not need any treatment. These variations in buccal segment occlusion and severity tend to reflect the underlying skeletal pattern which also varies from marked retrusion to near normal. This is reflected in the SNB angle in the sample (Table 1) with a range from 70.0 to 83.0 degrees. Similarly the facial plane angle varies between 77.0 and 91.0 degrees. The lower arch may show no crowding in some cases or quite severe crowding in others. The lower incisor position is usually retropositioned to the APo line to a varying extent. However it should be noted that the mean lower incisal angulation to mandibular

plane is about normal at 90.3 degrees although the range in the sample is from 82.0 to 101.0 degrees. However the mean upper incisal angulation to Frankfort plane at 98.6 degrees is well below the norm of 110 degrees and therefore the interincisal angle is increased. Note that the lowest value recorded for interincisal angle (123 degrees) is still greater than the mean inter-incisal angle for the Class II division 1 group. The increased inter-incisal angle is almost pathognomonic of the division 2 group. The variation in incisor angulations reflects the degree of skeletal retrognathism in the particular case. The classical type is easily identifiable and its features are more consistent than in any other Angle class.

Thus the features of the Class II division 2 type include :

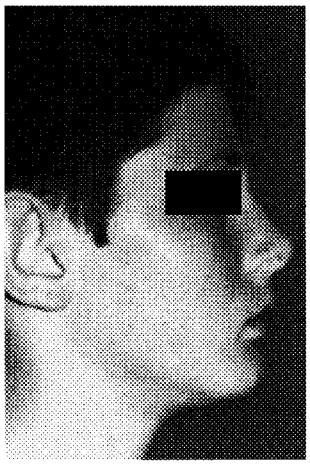
1. Retroclined upper central incisors with proclined and overlapping upper lateral incisors
2. Increased interincisal angle
3. Deep overbite
4. Crowding in varying degrees
5. Brachyfacial pattern with horizontal growth emphasis
6. Retrusive lower lip with high upper lip line
7. Broad square gonial angles
8. Prominent symphysis clinically and on the cephalogram
9. Class II buccal segment relationship of varying degrees
10. Skeletal Class II pattern varying from near normal to markedly retropositioned.
11. A tendency to higher muscular forces of the mandibular elevator muscles

Some workers have insisted that due to a deep locking bite, an abnormal closure path of the mandible can be demonstrated in Class II division 2 patients with posterior displacement of the condyles. This is very difficult to demonstrate. Older patients with this type of malocclusion may show progression of the deep bite causing palatal trauma behind the upper incisors and lower labial trauma. Occasionally there may be considerable tooth wear of the palatal aspect of the upper incisors and the incisal edges of the lower incisors.

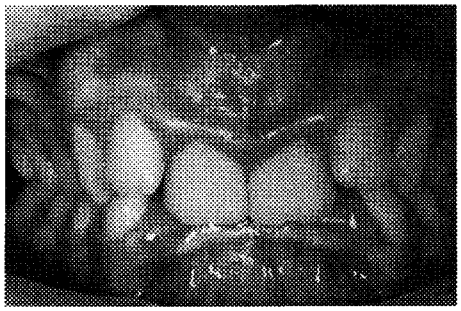
The aims of treatment are to unlock the occlusion and correct the overbite, at the same time correcting the buccal segment relationship to Class I in non-extraction cases. Because of the tendency to deep bite and a horizontal growth emphasis, extraction of bicuspids is usually not a preferred treatment option in the young patient with potential growth remaining. Where the incisors are retropositioned in the profile and the interincisal angle is increased, arch alignment without extractions is usually preferable. In most instances, considerable torquing of the upper central incisors and overcorrection of the lateral incisors will be required to achieve a stable result. Depending on the original position of the lower incisor to the APo line, they will be proclined very slightly to support the lower lip and achieve a better inter-incisal angle in association with upper incisor torquing. Providing the buccal segment occlusion is corrected, the incisors are not significantly proclined and the retention

(Case CK)

SNA	88°	MPA	21°	APt Nav	+1.5 mm	MxIFHP	91°
SNB	82°	F Angle	89°	PoNav	-3.5 mm	MdlMP	85°
ANB	6°	F Axis	91°	P/AFHt(.75)	0.73	IIA	164°
Wits	5 mm	LFHt	42°	LLEL	-1 mm	MdlAPo	-7 mm



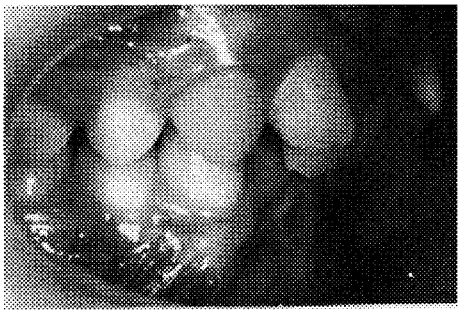
(a)



(b)



(c)



(d)

Fig. 1: (a-d) Records of a Class II division 2 malocclusion.

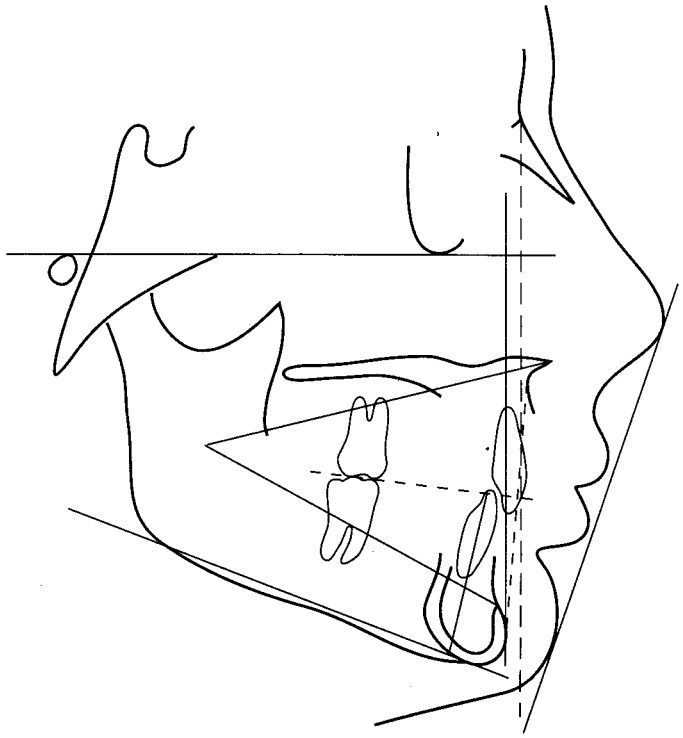


Fig. 2: Lateral head tracing of same case shown in Fig. 1.

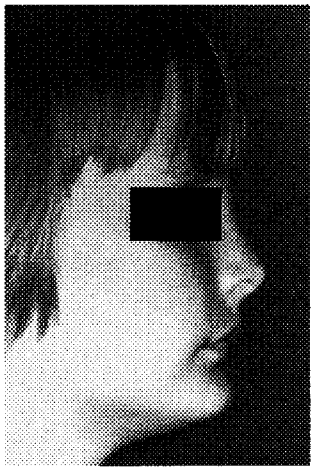
period is adequate, relapse is not a significant issue in the majority of cases treated in the growth phase. However as the patient becomes older and growth potential diminishes, nonextraction treatment becomes more difficult. In severe adult cases with marked incisor retroclination, reduced face height and a very deep bite, orthodontic treatment alone may be unfeasible. A combination of orthodontics and orthognathic surgery will be more rewarding. The surgery, usually involving a bimaxillary procedure, will allow correction of the reduced face height and overbite by jaw movement rather than tooth movement.

Classically the division 2 type exhibits a brachyfacial skeletal structure with a retrusive profile pattern (Figs. 1,2 - CK). This case displays most of the expected features with a supramental groove but the lower lip is not excessively retrusive to the E line. Thus we might characterise the case as a brachyfacial pattern with slight retrusion of the mandible and retroclination of the upper and lower incisors associated with a deep bite. It is not a severe skeletal pattern.

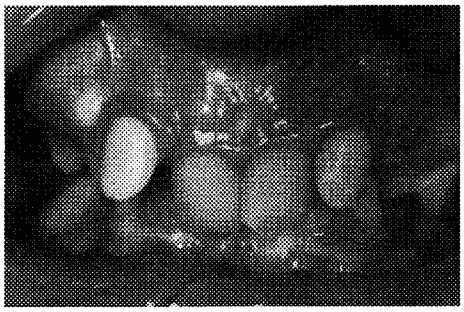
The dominant impression of this case and the class generally is a lower than average facial height reflected in the Frankfort mandibular plane angle and lower facial height. The soft tissues are also characteristic with high lower lip line, supramental groove, over-controlling lips although the lower lip is often well behind the E line. These cases are crowded from the front, the incisors being restricted by the lips

(Case DC)

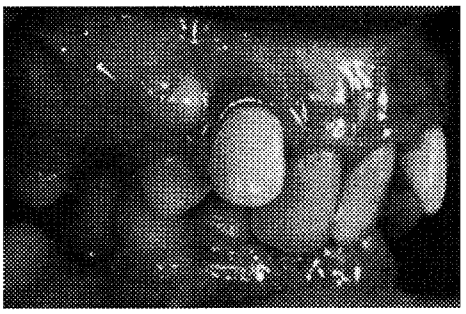
SNA	80°	MPA	11°	APt Nav	-4 mm	MxIFHP	78°
SNB	74°	F Angle	87°	PoNav	-6 mm	MdIMP	86°
ANB	6°	F Axis	100°	P/AFHt(.75)	0.78	IIA	185°
Wits	8 mm	LFHt	35°	LLEL	-8 mm	MdIAPo	-17 mm



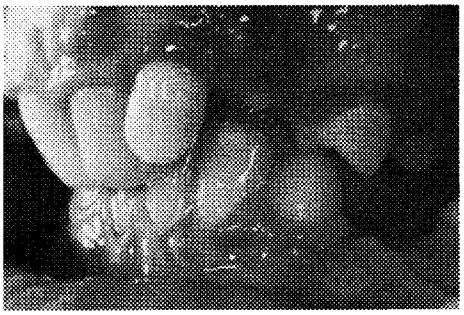
(a)



(b)



(c)



(d)

Fig. 3: (a-d) Records of a Class II division 2 malocclusion.

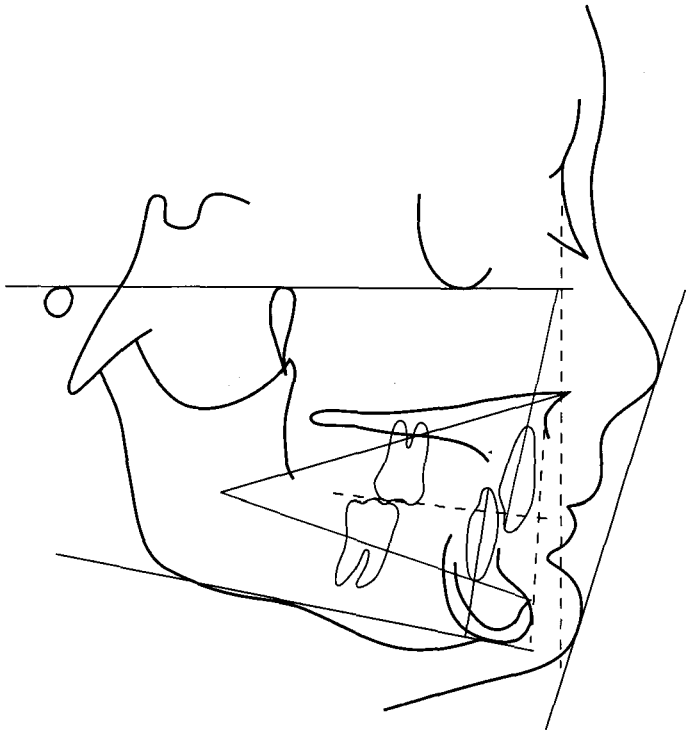


Fig. 4: Lateral head tracing of same case shown in Fig. 3.

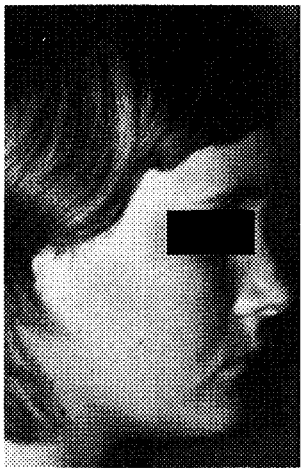
against the buccal segments. This impression is borne out by the angulation of the incisors and cuspids, which are upright or distally inclined. The mandible usually shows a strong prominent symphyseal shadow on the cephalogram and in extreme cases the facial region looks very square with a significantly reduced lower facial height.

The next case (Figs. 3,4 – DC) shows an extreme malocclusion with a classical incisor arrangement, deep bite and double incisor retroclination. The skeletal pattern suggests an extreme brachyfacial type with a lower facial height of only 35 degrees and a facial axis of 100 degrees. The upper incisors are very retroclined at 78 degrees to the Frankfort plane and the inter-incisal angle is extremely high at 185 degrees. The lower incisor is 17 mm behind the APo line. Note that the SNA value is 80 degrees which is not greatly abnormal. The skeletal pattern is square with a reduced anterior face height and deep bite.

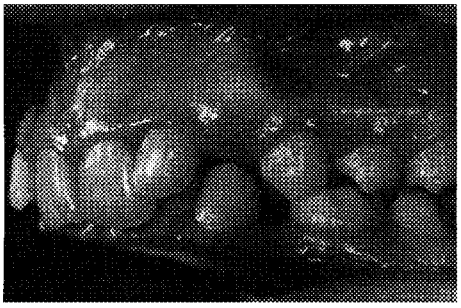
Note the heavy protrusive symphyseal outline which is often a feature of the severe Class II division 2 malocclusion. Interestingly, the angle of the lower incisor to the mandibular plane is 86 degrees and not too far from normal. However both the maxillary and mandibular bony bases are retrusive to the nasion vertical line. A case such as this shows the importance of using an integrated skeletal analysis rather than relying on a minimum subset of values such as SNA and SNB. Treatment in this case would be to decompensate the upper incisor angulations causing a substantial increase in overjet to be followed perhaps by orthognathic surgical

(Case SB)

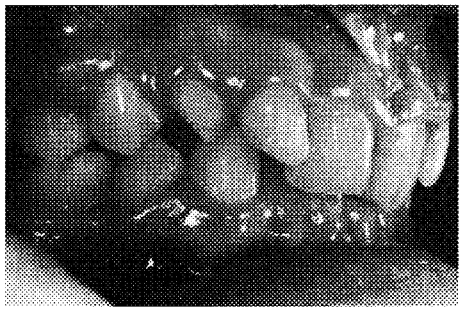
SNA	78°	MPA	18°	APt Nav	-2 mm	MxIFHP	98°
SNB	75°	F Angle	89°	PoNav	-2.5 mm	MdlMP	85°
ANB	3°	F Axis	97°	P/AFHt(.75)	0.67	IIA	158°
Wits	2.5 mm	LFHt	37°	LLEL	-5 mm	MdlAPo	-6 mm



(a)



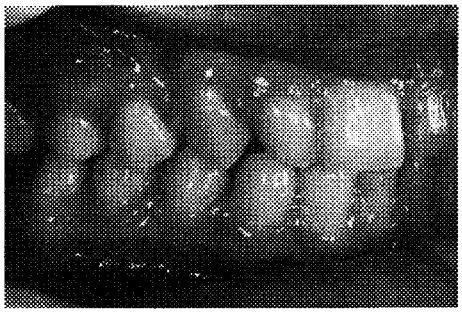
(b)



(c)



(d)



(e)

Fig. 5: (a-c) Pre-treatment records of a Class II division 2 malocclusion (d,e) post-treatment records at debanding.

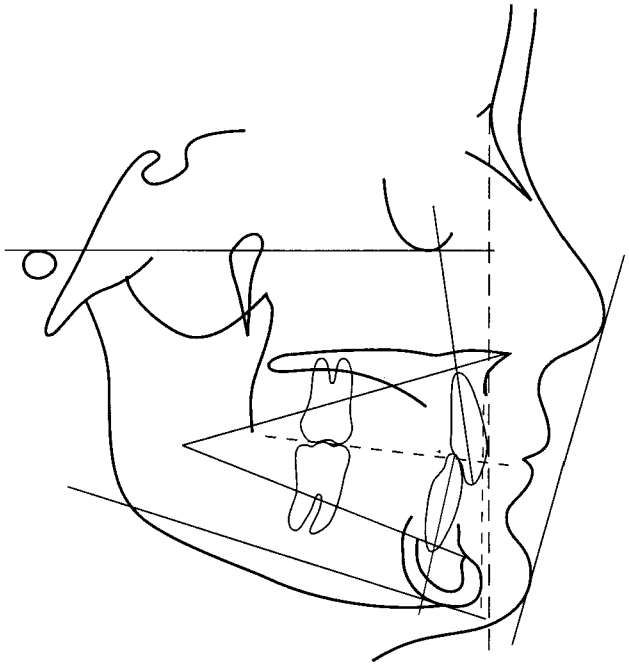


Fig. 6: Lateral head tracing of same case shown in Fig. 5.

correction of the overjet. Another alternative might be a functional appliance after incisor decompensation. This obviously is a very severe malocclusion.

Case SB (Figs. 5,6) displays the classical Class II division 2 brachyfacial morphology with a lower face height of 37 degrees and a mandibular plane angle of 18 degrees. Both upper and lower incisors are retroclined and the lower lip lies at -5mm to the E line. Both the maxilla and mandible are slightly retrusive to the nasion vertical line but the skeletal pattern is not extreme. There is a slight supramental groove. There is slight space loss in the lower arch.

Treatment involved full fixed appliances with light Class II elastics to coordinate the upper and lower arches. There was a need to regain a small amount of lower arch space. Extractions in the lower arch would make it very difficult to achieve a satisfactory result in harmony with the facial profile. The post-treatment results show that the objectives of treatment have been met. Most of these types of case are readily treated in the late mixed – early adult dentition period when the patient is still growing and the occlusion is yet to develop to the full adult state. If treatment is delayed by exfoliation, considerable bite improvement can be obtained with a simple bite plate to reduce the overbite. Some clinicians have advocated early proclination of the upper incisors to be followed by a period of functional appliance treatment to correct the arch relationships. Final detailing can be done with fixed appliances.

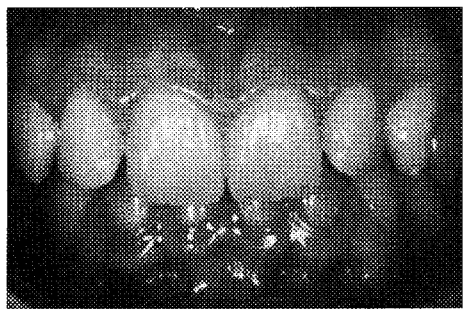
Case SJ (Figs. 7–10) shows a definite brachyfacial malocclusion with retrusion of both the maxilla and mandible. The skeletal pattern is not extreme although the

(Case SJ)

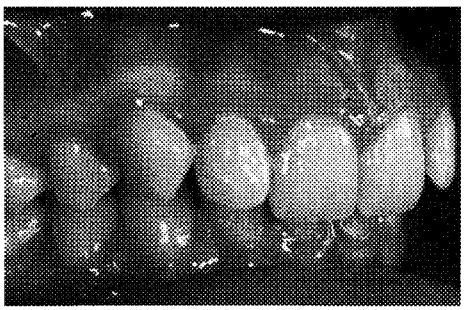
SNA	83°	MPA	25°	APt Nav	-3 mm	MxIFHP	92°
SNB	77°	F Angle	84°	PoNav	-10 mm	MdlMP	87°
ANB	6°	F Axis	96°	P/AFHt(.75)	0.66	IIA	156°
Wits	4 mm	LFHt	39°	LLEL	-2 mm	MdlAPo	-5 mm



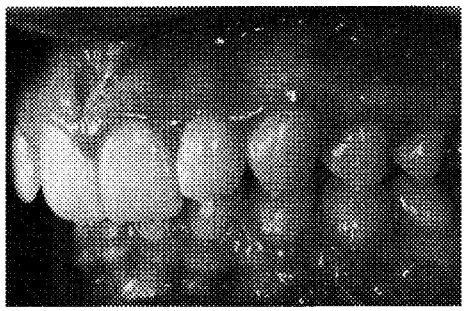
(a)



(b)



(c)



(d)

Fig. 7: (a-d) Pre-treatment records of a Class II division 2 malocclusion.

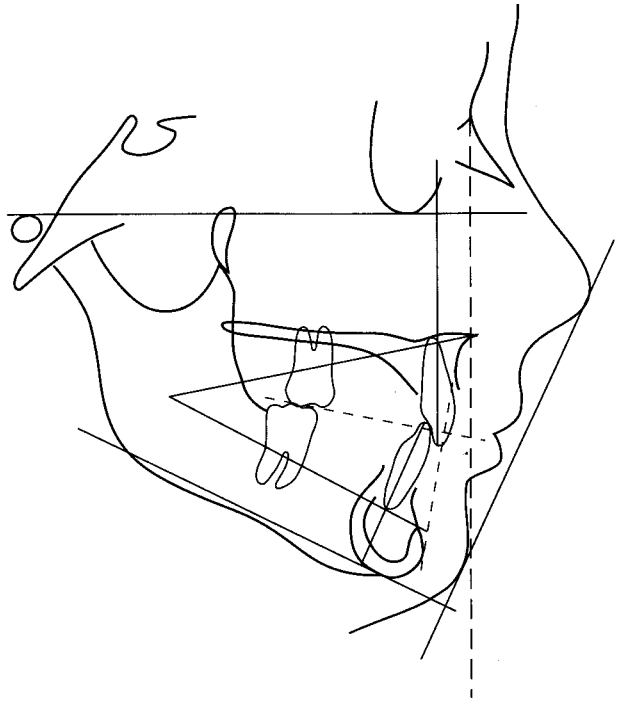


Fig. 8: Pre-treatment lateral head tracing of same case shown in Fig. 7.

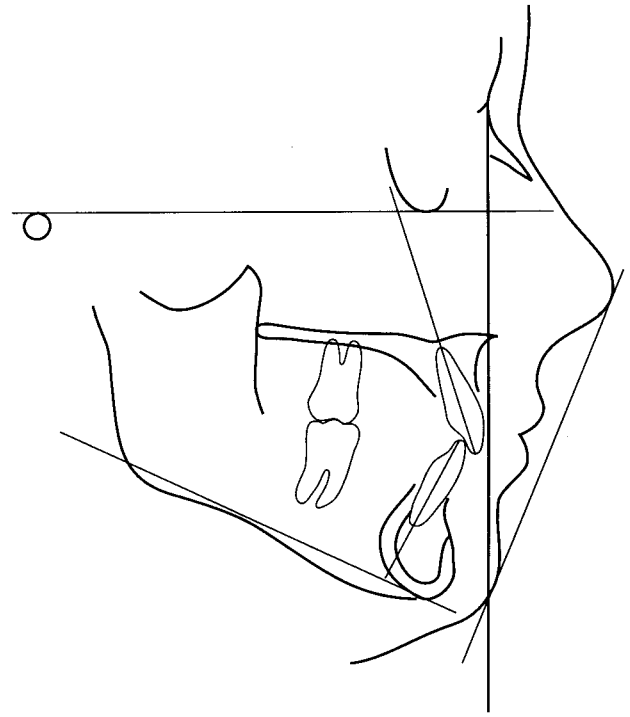
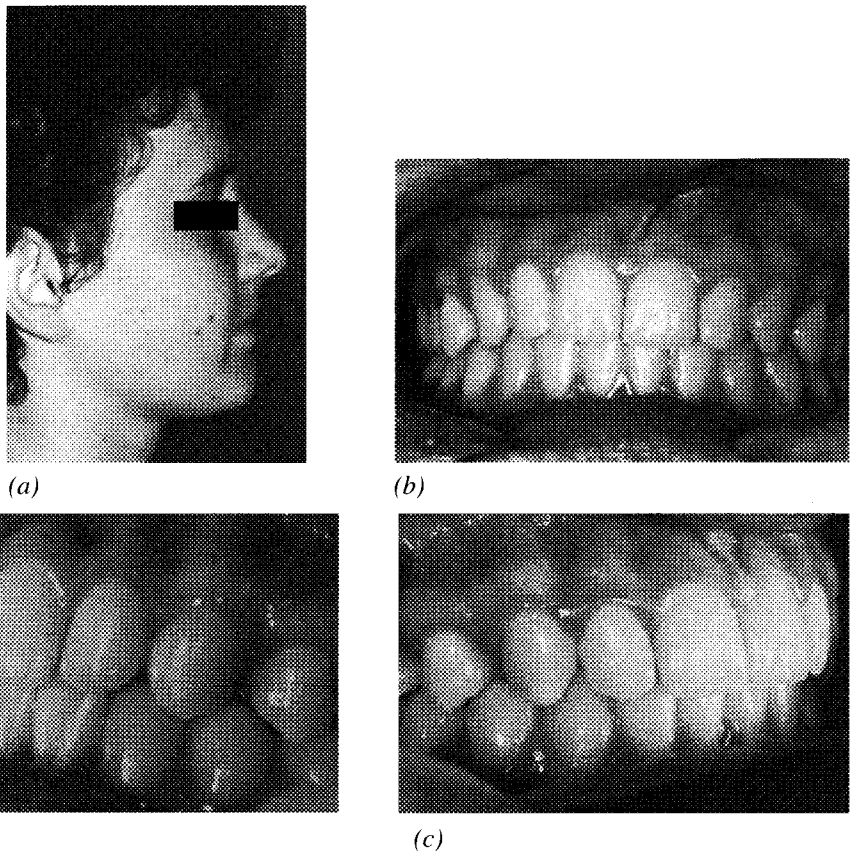


Fig. 9: Post-treatment tracing of same case shown in Fig. 7.



(a) *(b)*

(c) *(c)*

Fig. 10: (a-d) Post-treatment records of same case shown in Fig. 7.

retrusion of pogonion to the nasion vertical is relatively high at -10mm. The facial axis value is well above the expected norm and lower facial height is only 39 degrees. A slightly stronger horizontal growth pattern might be expected. Treatment will be directed to coordination of the upper and lower arches with reduction of the overbite and Class II correction of the buccal segment relationships which are not quite in a full cusp Class II relationship. This should be accompanied by torque of the upper incisors to correct their angulation to the Frankfort plane. The soft tissues in this case are compromised with a convex profile. Note the absence of the usual supramental groove in the lower lip. Fortunately the lower arch alignment is good and extractions are not required

The post-treatment records (Figs. 9, 10) show a substantial improvement. The occlusion is in Class I and the inter-incisal angle has improved with apical root torque of the upper incisors. In spite of the nonextraction treatment there has been little change in the profile although the chin position has improved slightly.

The final case (Figs. 11,12 – RH) is an atypical Class II division 2 malocclusion with retroclination of the four upper incisors and a high inter-incisal angle. Note that while this case is still technically a division 2 type according to Angle's definition, it does not have the characteristic brachyfacial pattern. There is a double incisor

(Case RH)

SNA	77°	MPA	30°	APt Nav	-7 mm	MxIFHP	83°
SNB	74°	F Angle	83°	PoNav	-16 mm	MdIMP	73°
ANB	3°	F Axis	84°	P/AFHt(.75)	0.64	IIA	173°
Wits	2 mm	LFHt	47°	LLEL	-6 mm	MdIAPo	-6 mm

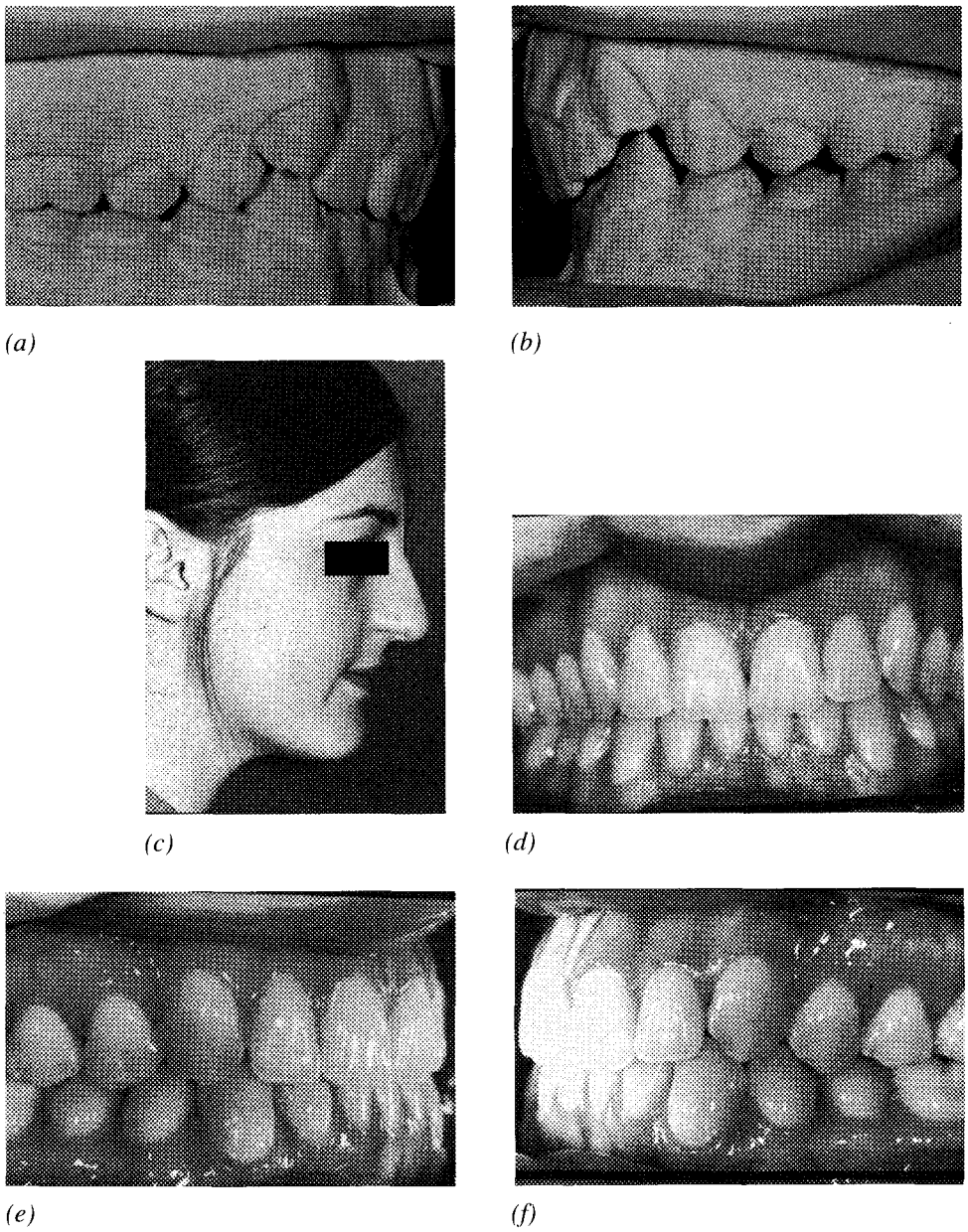


Fig. 11: (a-b) Pre-treatment records of an atypical Class II division 2 case (c-f) post-treatment records of same case seven years out of retention.

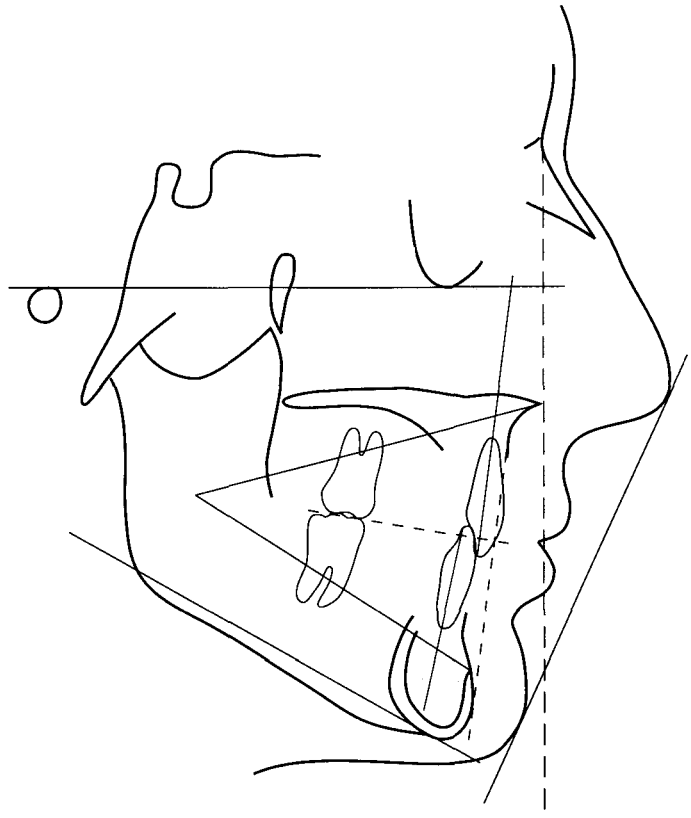


Fig. 12: Pre-treatment lateral head tracing of same case shown in Fig. 11.

retroclination with a very high inter-incisal angle. The lower incisor angle to the mandibular plane is only 73 degrees. However, the lower face height and mandibular plane angles are above normal. Both A point and pogonion are very retrusive to the nasion vertical line and the lower lip is well behind the E line. This is not a typical brachyfacial deep bite case and yet must still be classified as a Class II division 2 malocclusion. The objectives of treatment are again determined by the retropositioning of the upper and lower incisors and every attempt was made to treat on a nonextraction basis. Both arches were rounded out with reduction of the overbite and coordination. Ultimately posterior arch crowding required the extraction of second permanent molars and the third molars erupted into good occlusion. The post-treatment records show the occlusion seven years out of retention. The case is stable and the result as good as could be achieved by orthodontic treatment.

The treatment of the above case raises several important diagnostic issues including the reangulation of the incisors during treatment and the long term stability of the result. Generally the aim is to avoid substantial change in the lower incisor angulations from the pretreatment positions in the expectation that some relapse will occur. Where the lip morphology is obviously abnormal with a deep supramental groove and perhaps incompetent function, slight reangulation is at least justifiable in the presence of a badly compromised skeletal pattern. The options for treatment

are critically limited by abnormal incisor angulations which contraindicate extractions which will cause further deterioration. While surgery may offer an alternative in many instances, there are occasional cases where surgery is not an option and orthodontics offers the only mode of treatment. When the result is satisfactory and stable it is easier to justify treatment objectives in hindsight. Although the objectives of retention are often difficult to define, the treatment of such a severe incisal relationship requires prolonged retention and resolution of the third molar eruption status by surgical removal if necessary.

In the past, some clinicians have advocated a form of compromise treatment in the milder Class II division 2 cases. This involves extraction of upper first or second bicuspids, retraction of the cuspids and alignment of the lateral incisors with removable appliances. At the same time the overbite is reduced by means of a bite plane. Such treatment will fail on several counts. The inter-incisal angle remains unchanged and the overbite will largely relapse. The lateral incisor angulations cannot be over-corrected and will relapse to some extent. Often the buccal segments in these milder cases are not in full Class II relationship so that extraction of an upper bicuspid creates far too much space and residual spaces may remain. Almost invariably treatment finishes with the buccal segments still not forward into a full Class II. The upper cuspid which is often upright to begin with, is now distally inclined and in a cusp-to-cusp relation rather than a Class I relation to the lower cuspid. The incisors are still retroclined although the overbite has been temporarily reduced by posterior over-eruption due to the anterior bite plane. The general result is an occlusion which is unstable and will relapse to some extent. In most instances, removable appliances are not recommended in the correction of Class II division 2 malocclusions.

Because of the tendency to retro-positioning of the lower incisors, extractions are usually avoided in the lower arch. However, on occasions, the amount of crowding in these cases is simply too much to allow non-extraction treatment and extractions will have to be done. This is even more likely in the older patient. Because of the inherent difficulties of space closure in brachyfacial cases and the likelihood of further lip retraction, the operator may choose to extract second bicuspids or, less often, second molars. In both instances, fixed appliance treatment is required and will be prolonged. It is often forgotten that the objectives of bite opening and space closure are mutually antagonistic. Space closure will tend to cause deepening of the bite while the mechanics of bite opening will tend to increase space within the arch. The heavy bite in these patients results in constant deformation of the lower arch wire which is "bitten out" in the region of the extraction spaces. Extraction treatment and space closure in the Class II division 2 malocclusion can be a very testing exercise for both the patient and the clinician.

The general shape of the mandible in these patients is brachyfacial with a square gonial angle. As the mandible grows there may be minimal posterior extension of the alveolar arch length. This means that if treated non-extraction there may not be

enough space for eruption of third molars and impaction of the third molars should be monitored.

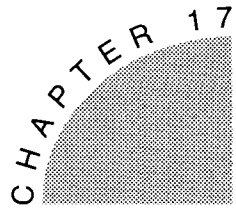
Because of the need for over-correction of the incisal segments and the need to unlock the anterior occlusion, Class II division 2 cases will often respond well to interceptive treatment in the middle to late mixed dentition phase. This interceptive treatment is easily accomplished with limited fixed appliances, inter-maxillary elastics and, when indicated, headgear. With these appliances it is possible to prevent continuing deterioration in the anterior occlusion and to place the occlusion in a better relationship allowing optimal development and the achievement of long-term stability.

An alternative interceptive method which may be considered is the activator or functional appliance. While these cannot achieve any major changes in tooth angulation or rotations, in cases with reasonably good arch alignment they may achieve unlocking of the occlusion, correction of the buccal segments and a useful reduction in overbite. A preliminary phase to procline the upper incisors "converting" the case to a Class II division 1 malocclusion is required prior to further treatment with a functional appliance. After the correction of the buccal segments with the functional appliance, fixed appliances are used to complete treatment. Arguments persist as to the action of functional appliances, some claiming a stimulation of condylar growth. They may certainly give valuable assistance to the developing occlusion. In very severe cases, where treatment may not be immediately available, the general practitioner can perform a useful service by placing an upper bite plate. This is particularly true where there may be dental or soft tissue damage due to the deep overbite. No attempt is made to treat the case, but simply to intercept and decrease the overbite prior to fixed appliance treatment. Some operators claim that by angling the bite plane upward and forward, a functional appliance effect may be induced at the same time.

The use of headgear in the treatment of Class II division 2 malocclusion will again depend on evaluation of the antero-posterior position of the maxilla. Examination of the values for A point convexity (Table 1) shows that maxillary prognathism is less common than in Class II division 1 types and therefore heavy headgear forces may not be advisable in most cases. However, in some cases the degree of maxillary prognathism will invite the use of headgear to help correct the buccal segment relationships and restrain further forward maxillary development. In other cases where the maxilla is less prognathic, lighter headgear forces may be used to help anchorage rather than drive the upper arch distally. Where the maxilla and mandible are excessively retropositioned, orthognathic surgery may offer the best option with a bimaxillary forward shift of both maxilla and mandible.

The operator should be aware of the stage of skeletal development to ensure that definitive orthodontic treatment is commenced before the puberal growth spurt. The more difficult the malocclusion, the more important it becomes to treat prior to this period of enhanced growth and certainly not afterwards. In most boys this is

not a problem. However, in girls the puberal growth spurt starts at about 11.5 years and in some cases earlier. This means that the growth spurt may be well under way before complete eruption of the permanent dentition. In both boys and girls, the later stage of definitive treatment may be made a lot easier by an earlier stage of interceptive treatment. Treatment may involve two phases in the developing Class II division 2 malocclusion which is to be treated without permanent extractions. The first phase is commenced after full eruption of the upper and lower permanent incisors. The appliances involve banding of first permanent molars and bonding the four permanent incisors in both arches – often termed a " 2 by 4" appliance. Utility arches with light Class II elastics are used to open the bite and hold the arch length. Occasionally, extractions of deciduous cuspids or first deciduous molars are indicated to help alignment or to de-crowd erupting permanent teeth. After attainment of incisor alignment and reduction of the overbite, retainers are placed until complete eruption of the cuspids and bicuspids after which full appliances are replaced and treatment completed. This two phase treatment may greatly help the correction of the more severe Class II division 2 case but requires good patient cooperation over an extended period and a willingness of the parent to accept the increased costs of treatment.



CLASS III MALOCCLUSION

Class III malocclusion is defined as any malocclusion with a mesial relation of the lower arch to the upper arch where the lower first permanent molars occlude more than one half cusp width mesial to the normal molar relationship. This type is often described as a mesiocclusion. There is a wide diversity of types in the Class III category varying from very large mandibles to small underdeveloped maxillae or a combination of both. The terms Class III and mandibular prognathism are often used interchangeably but in case analysis it is important to differentiate the skeletal and occlusal components.

The skeletal structure in Class III cases varies markedly but two extreme types have been identified - Type I and Type II (McCallin, 1955). Nevertheless it must be remembered that there is a gradation between these two extreme types so that a particular case may not fit neatly into either category. Mills (1966) drew attention to the wide spread in the values of skeletal variables such as SNA, SNB and mandibular plane angle with the implication that there is no absolutely characteristic Class III skeletal morphology and again highlighting the necessity to carefully examine the components of the individual case before formulating a treatment plan.

TYPES

The Type I patient displays a long mandible with an increased gonial angle and a crowded contracted maxillary arch. There is an increased lower face height with a long lower face. There may be an open bite or reduced overbite. In the more severe cases there may be occlusion on the posterior teeth only. The soft tissues do not appear to play a major part in the etiology of Class III malocclusions. At rest the tongue lies in the floor of the mouth but on swallowing may be thrust between the incisors. Often the lip morphology is incompetent and active contraction is required to achieve an anterior oral seal. These activities are secondary to the skeletal morphology. Some patients show marked mentalis contraction with dimpling of the chin area. At rest the lower lip may be everted from the lower incisors. The swallowing pattern seems not to involve firm contact of the dorsum of the tongue with the palate. The upper arch is usually crowded and narrower than the lower arch with a resultant crossbite. Mandibular displacement on closure to occlusion may occur as a result of any crossbite.

The Type II patient is also characterised by a long mandibular corpus but the gonial angle is below average. The maxillary arch is often not particularly contracted or crowded. Lower face height is not markedly abnormal. The soft tissue profile reflects

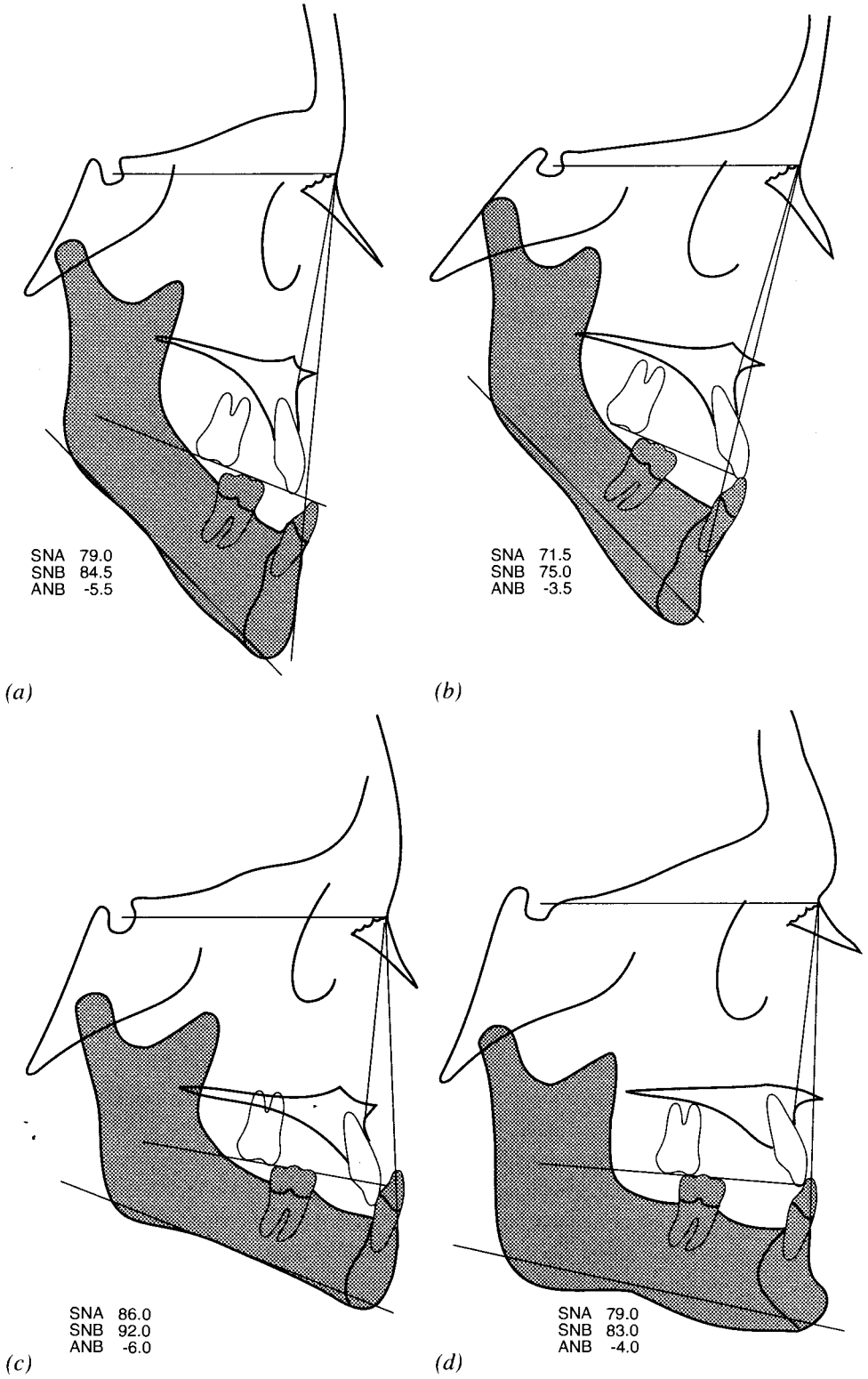


Fig. 1: (a,b) Divergent skeletal patterns associated with Class III malocclusions (c,d) convergent skeletal patterns associated with Class III malocclusions. (Redrawn from Jacobson et al, 1974).

the underlying skeletal abnormality. Frequently there is a distinct forward displacement of the mandible after first contact of the incisal edges with a forward and upward rotation of the mandible such that the overbite is positive although reversed. The lower incisor angulations are not usually retroclined. Some researchers claim that there is overclosure of the mandible into the habitual interocclusal position.

Jacobsen et al (1973) also described two contrasting types of Class III malocclusion which they termed divergent and convergent (Fig. 1). These are equivalent to the Type I and Type II described by McCallin (1955). The divergent type showed an anterior openbite, high gonial angle and divergent palatal, occlusal and mandibular planes. The convergent type showed a lower gonial angle, less divergence of the palatal, occlusal and mandibular planes and a tendency to a deep reverse overbite. The values in Table 1 suggest that the divergent and convergent types are the extremes of the range, with many other combinations of traits in between the extremes. The range of variation is akin to that seen in the Class II types. Mandibular plane angle varied from 18 degrees to 46 degrees with an average of 28 degrees. The angles SNA and SNB were equally variable. The lower incisor to mandibular plane angle ranged from 64 degrees to 113 degrees.

Variable	Mean	Min	Max	s.d.
SNA	80.1	68.0	95.0	4.8
SNB	81.0	71.0	94.0	4.5
ANB	-1.0	-9.0	6.0	3.2
Facial axis angle	90.3	79.0	99.0	4.8
Facial plane angle	90.4	84.0	103.0	3.7
Mandibular plane angle	28.1	18.0	46.0	5.4
Lower face height	46.4	39.0	62.0	4.6
Mx incisor to Frankfort plane	115.6	103.0	129.0	6.5
Md incisor to mandibular plane	86.7	64.0	113.0	10.6
Inter incisal angle	132.1	111.0	156.0	9.3
Md incisor to A Pog (mm)	3.6	-2.0	11.0	2.8
A point convexity (mm)	-1.7	-14.0	7.0	3.9
Lower lip to E line (mm)	-2.3	-13.0	7.0	3.7
Overbite (mm)	1.5	-4.0	6.0	1.8
Overjet (mm)	-0.2	-7.0	4.0	2.3

Table 1: Descriptive statistics for variables measured on 49 consecutive cases of Class III malocclusion.

Sperry et al (1977) in an interesting study of treated cases examined the parameters which prompted clinicians to recommend orthodontic treatment as opposed to surgical treatment of Class III cases. Orthodontic treatment was more likely to be recommended in the less divergent cases while surgical treatment was more common in the divergent cases. Thus we might hypothesise that the more divergent the case at an early age the less likely will be the success of orthodontic treatment.

Ellis and McNamara (1984) examined 302 adult cases of mesio-occlusion and assessed SNA, SNB, facial angle and nasion perpendicular. They reported that the most commonly found Class III malocclusion (30%) showed a combination of mandibular protrusion and maxillary retrusion. Maxillary retrusion alone was found in 20 per cent of the sample and mandibular skeletal protrusion alone was found in 19 per cent (Table 2). Other less common combinations include retrusion of both the maxilla and mandible in 8 per cent of the sample. Thus while mean values will show group trends, their interpretation should always be tempered by detailed analysis of the individual's problems before formulating a treatment plan.

	Maxilla	Mandible	Number	Percentage
1	Retrusive ◂	Protrusive ▸	91	30.1
2	Retrusive ◂	Neutral –	59	19.5
3	Neutral–	Protrusive ▸	58	19.2
4	Protrusive ▸	Protrusive ▸	45	14.9
5	Retrusive ◂	Retrusive ◂	24	7.9
6	Neutral –	Neutral –	14	4.6
7	Neutral –	Retrusive ◂	5	1.6
8	Protrusive ▸	Neutral –	5	1.6
9	Protrusive ▸	Retrusive ◂	1	0.3

Table 2: Combinations of maxillary and mandibular skeletal positions in 302 cases with mesio-occlusion. (After Ellis and McNamara, 1984.)

Guyer et al (1986) examined the components of Class III malocclusions in young patients aged 5 to 15 years. They compared Class I and Class III occlusions. They showed that several skeletal descriptors may allow early identification of the Class III type. SNA, facial plane angle, gonial angle and lower incisor angulation were significantly different in the Class III group. Of particular interest was the change in lower incisor angulations in the two groups with progressive proclination in the Class I group and progressive retroclination in the Class III group as development occurred (Fig. 2). They summarised that Class III malocclusions were more likely to display maxillary retrusion, a higher than average gonial angle, increased mandibular plane angle, increased lower face height, proclined upper incisors and retroclined lower incisors. The skeletal abnormalities tend to become more pronounced with age.

Some texts have made a particular point of the pseudo Class III type which is defined as a Class I with forward displacement of the mandible into anterior crossbite. As the incisors erupt they come into edge-to-edge contact which induces the forward displacement. The distinction is often artificial as most pseudo Class III cases are Class I malocclusions with a prognathic tendency. The mandibular displacement is not peculiar to these and may be seen in any Class III. In the Class III group there is a continuum from mild to very severe with most pseudo Class III types representing

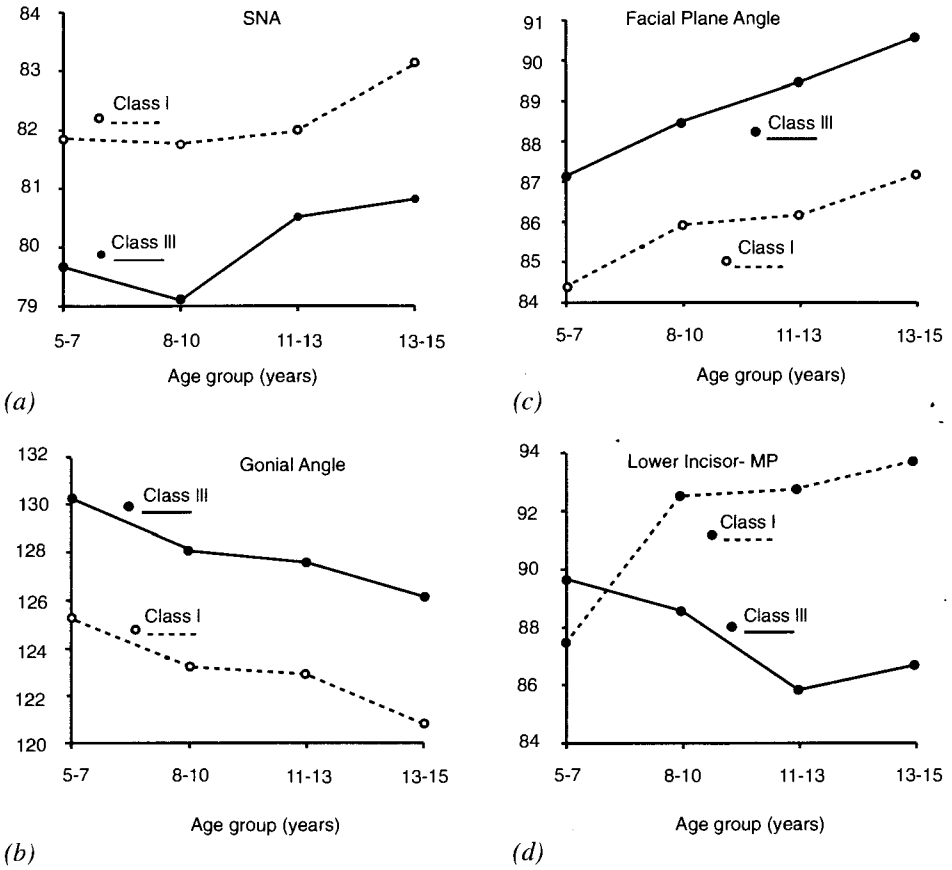


Fig. 2: Comparison of cephalometric values in Class I and Class III samples (a) SNA values are lower in the Class III group (b) gonial angle is higher in the Class III group (c) facial plane angle is higher in the Class III group (d) lower incisor to mandibular plane angle increases in the Class I group and decreases in the Class III group with development. (Redrawn from Guyer et al, 1986.)

the mild cases with forward displacement of the mandible. Providing there are no other complicating factors they may be treatable with a removable appliance by simple forward tipping of the upper incisors to a correct positive overjet relationship.

TREATMENT

The aim of orthodontic treatment will be largely determined by the underlying skeletal severity. Where the principal etiological factor is retrusion of the maxilla, treatment should be directed to protraction of the upper arch. Other qualifying factors include the amount of reverse overbite, the angulations of the upper and lower incisors and the degree of forward mandibular displacement. The larger the skeletal discrepancy, the more difficult it is to treat by movement of teeth alone. Where overbite is reduced or there is an open bite, correction of the reverse overjet will not be maintained by tooth contact. The greater the amount

of forward mandibular displacement, the easier will be the correction when the true retruded position of the mandible is adopted. Where there is a combined etiology of maxillary retrusion and mandibular protrusion correction may require a bimaxillary surgical procedure with a forward shift of the maxilla and upper arch as well as a posterior shift of the mandible and lower arch. Many patients are less concerned by the occlusion than by the poor alignment of the upper arch and not uncommonly patients will fail to proceed with surgery once acceptable alignment of the upper teeth is achieved.

The other major consideration in Class III types is the amount of crowding in the maxilla. Where the maxilla shows underdevelopment relative to the mandible, there may be pronounced crowding. Extractions may be contra-indicated if the aim is to treat the case orthodontically. Lateral and antero-posterior expansion of the maxilla will be necessary to accommodate all teeth. While removable appliances may achieve useful expansion, the results are unpredictable and largely dependent on patient cooperation. A much more satisfactory result can be achieved with fixed appliances.

Treatment planning requires consideration of all three dimensions. Vertical excess with an open bite often will not be easily or satisfactorily treated orthodontically. Similarly excessive length of the mandibular corpus will not be satisfactorily masked by orthodontics alone. In those cases with marked lateral contraction of the upper arch, surgery may offer the most practical solution. Essentially the orthodontic correction of Class III malocclusion must be based on an accurate assessment of the severity of the problems in the three dimensions and determination of the possibility of satisfactorily masking the problems by orthodontic tooth movement alone such that at the end of treatment the upper and lower incisor angulations are acceptable and likely to remain stable. Additionally the resulting profile also must be acceptable.

Even rapid expansion of the upper arch with dysjunction of the midline suture will result in some tipping of the upper teeth to the buccal. Apart from a tendency to relapse, the upper to lower tooth angulations may make normal buccal occlusion difficult. The clinician must assess the pre-expansion angulations of the teeth. Surgical augmentation will encourage more bodily movement of the maxillae and help to minimise buccal flaring. If the final correction of the antero-posterior discrepancy is to be done surgically then the amount of buccal expansion must be calculated to ensure ultimate coordination of the upper and lower arch widths in the corrected positions.

The usefulness of removable appliances in the treatment of Class III malocclusions is limited in all three dimensions of the occlusion. In those cases with minimal skeletal discrepancies, significant corrections can be made with simple removable appliance which tip the upper incisors labially within the bounds of stability dictated by the angular relationships of the teeth to the maxillary base and to the lower teeth. Similarly, the less severe forms of buccal crossbite may be correctable by means of

a removable appliance or quad helix appliance. But as the lateral skeletal discrepancy increases and the buccal angulations become less favourable, the effectiveness of simple tipping decreases. Rapid maxillary expansion may offer a better result.

INTERCEPTION

Interceptive treatment may provide a better environment for continuing dentoalveolar development. Interception in the less severe cases is likely to be successful. In severe cases, no amount of tooth movement can compensate in either the vertical or saggital dimensions and surgery will be necessary. One of the main difficulties in management of these cases in the earlier growth phases is that the patient's appearance may be significantly compromised by a contracted and crowded upper arch. It is impractical to ignore this problem in severe cases on the basis that the patient may ultimately require surgery. Some form of interceptive orthodontic alignment in the upper arch may be required to provide an acceptable appearance during adolescent development. This will be followed by a second stage of treatment at a later date, perhaps in conjunction with surgery.

Difficulties arise in the severe cases where the interceptive treament substantially alters the dental arches and the pattern of dental development. If the malocclusion continues to deteriorate it is difficult to justify continuation of the original treatment plan if the liklihood of surgery increases. In those cases where orthodontic treatment has included permanent extractions in both the upper and lower arches, later surgical-orthodontic treatment may be compromised. Extraction treatment is essentially a form of compensation treatment based on the movement of teeth to mask the skeletal discrepancy. Surgical treatment on the other hand requires decompensation of the lower arch in particular in many cases. This is usually achieved by forward movement of the lower incisors and alignment without extractions. Thus if extractions have been done previously in the lower arch, presurgical decompensation will open the extraction spaces. Therefore the objectives of orthodontic treatment only as opposed to surgery and orthodontics may be in conflict.

Early interceptive treatment has included chin cup therapy which consists of a chin cup over the mandibular symphysis connected to a high pull headgear in an effort to restrain mandibular growth. Most studies suggest the main effect of the chin cup is to retrocline the lower incisors by pressing against the lower lip. Turley (1996) has indicated that interceptive treatment of Class III malocclusions with reverse traction and maxillary expansion can be expected to be successful in a high percentage of cases. Criteria for case selection were not provided. He has advocated that a first phase of treatment should commence while the patient is relatively young – in the mixed dentition. This first phase consists of rapid maxillary expansion and full time reverse traction to the maxilla. No attempt is made to achieve correction by compensating incisor movements at this time and the use of Class III elastics is limited. The main objective is orthopedic correction of the maxillary position which

is associated with downward and forward correction and posterior downward rotation of the maxilla. At the same time there is posterior rotational opening of the mandible. It is claimed that following correction of the Class III relationship subsequent growth of the mandible is directed more vertically, helping to maintain the correction. A second phase of treatment is undertaken when the permanent teeth erupt. In the time between these two phases reverse traction is applied as required.

While attempts have been made to predict the amount of forward growth of the mandible in Class III cases, the results are not dependable. Some cases undergo significant forward growth of the mandible in the puberal growth spurt but it is not predictable. One of the most useful aids to assessment is a thorough family history and when available family photographs may give a hint of expected outcomes in the individual. Most females will have completed mandibular growth by sixteen years and surgical correction round this time will usually not be subject to relapse due to growth. Males on the other hand may exhibit significant mandibular growth until about nineteen years of age. In both cases accurate estimation of the stage of physiological development is required by documentation of height increases and radiological estimates using hand-wrist films. Orthognathic treatment may commence before the completion of growth however this underlines one of the difficulties in management of these cases. If it is clear that surgery will be required, orthodontic alignment of the upper teeth may still be required at about 12 years of age in order to give the patient an acceptable appearance even though surgery may not be scheduled for another four years or more. A retainer may also need to be worn over this time.

CASE PRESENTATIONS

Figures 3 and 4 (Case AS) shows the records of a young female patient with a Type II or convergent Class III malocclusion. The SNA value is slightly less than normal while the SNB value is well above the normal or expected value of about 80 degrees. This is reflected in the increased Wits measurement of 8 mm. The facial angle is increased from an average of 87 degrees to 90 degrees again indicating a forward position of the chin. The facial axis measurement of 103 degrees is significantly increased above the expected normal of 89 degrees. In keeping with the convergent classification, the lower face height measurement of 35 degrees is 10 degrees less than the expected norm. The reduced anterior lower face height is reflected in the reduced naso-labial angle between the nose and the upper lip.

The Type II convergent Class III malocclusion is more likely to be predictably treated with orthodontic appliances and where there is substantial anterior displacement of the mandible on closure to occlusion, the problem may be treatable with relatively simple removable appliances. This is achieved by tipping the upper incisors forward to eliminate the displacement of the mandible. The pre-treatment deep overbite usually ensures that the post-treatment overbite will be adequate to eventually maintain the corrected positions of the upper incisors. However, care

(Case AS)

SNA	80°	MPA	24°	APt Nav	-4.5 mm	MxIFHP	112°
SNB	85°	F Angle	90°	PoNav	0 mm	MdlMP	85°
ANB	-5°	F Axis	103°	P/AFHt(.75)	0.73	IIA	135°
Wits	8 mm	LFHt	35°	LLEL	1 mm	MdlAPo	+4 mm

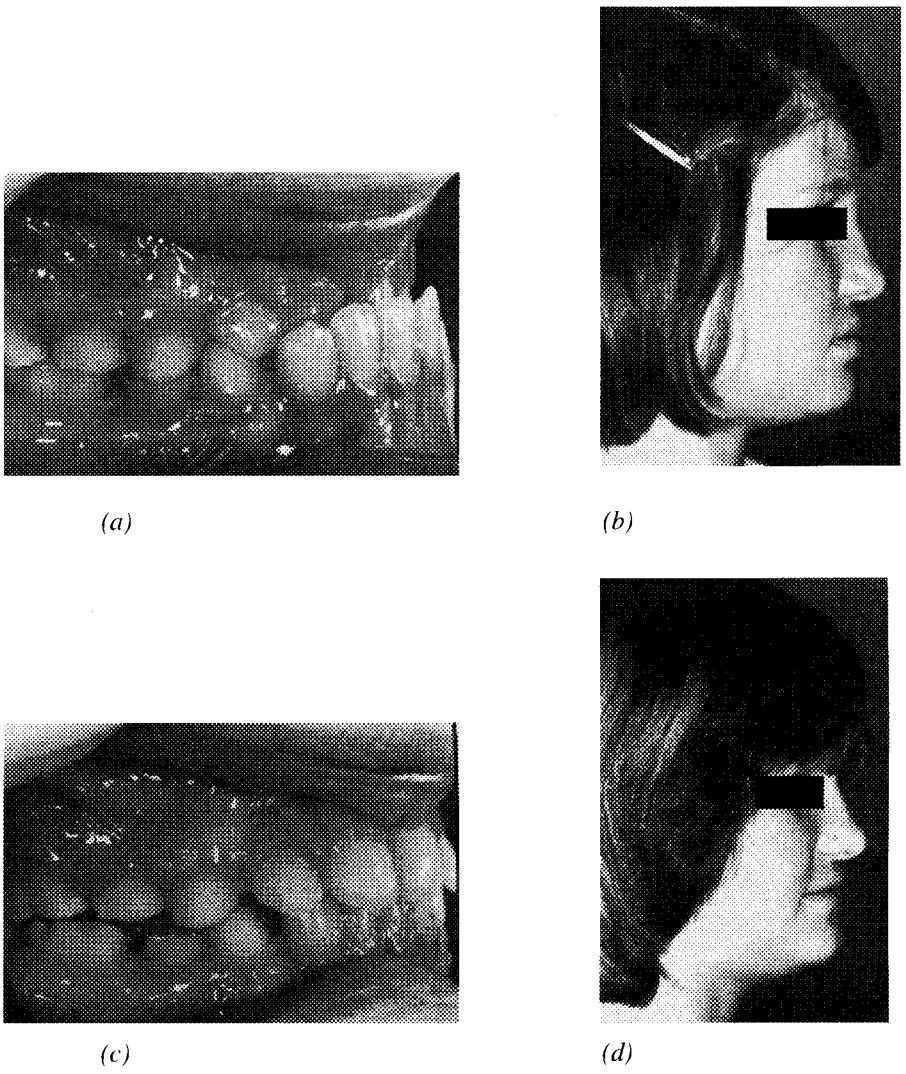
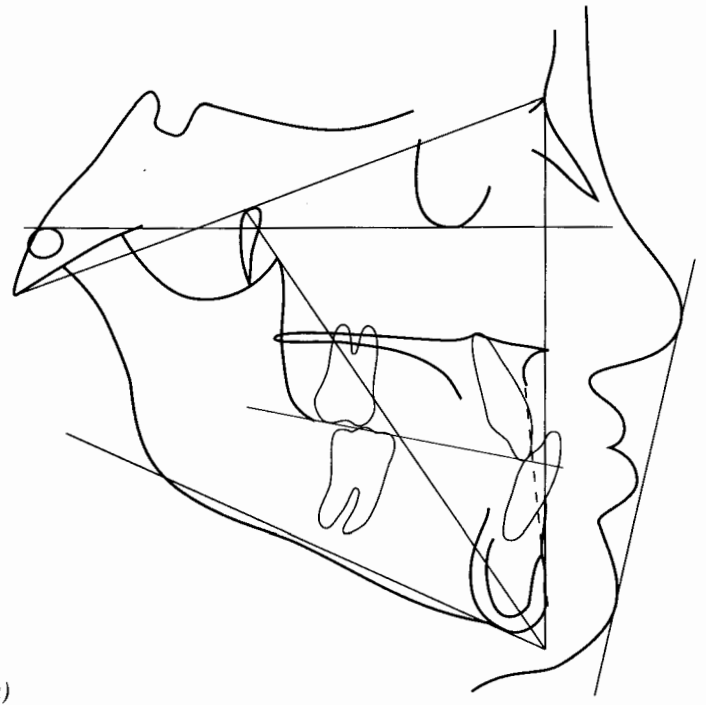
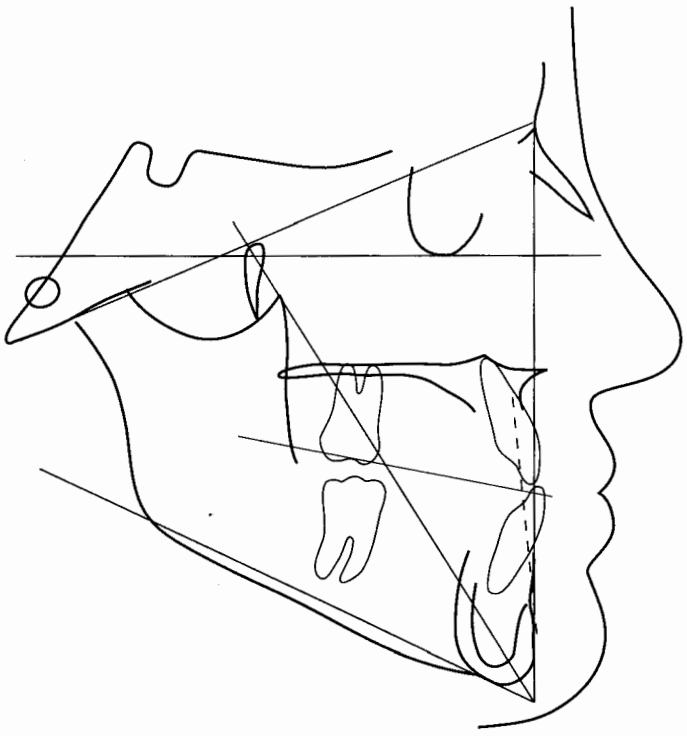


Fig. 3: (a,b) Pre-treatment records of a convergent type of Class III malocclusion (c,d) post-treatment records.



(a)



(b)

Fig. 4: Class III malocclusion (Type II convergent) (a) cephalogram taken in centric occlusion (b) cephalogram taken in fully retruded position of the mandible (same case as shown in Fig. 3).

must be taken to ensure that adequate retention is undertaken until the posterior occlusion settles and the upper incisors are not immediately subjected to the full load of the occlusion.

Of particular interest in this case is the cephalogram taken in the fully retruded position of the mandible (Fig. 4). The patient is able to retract the mandible to an edge-to-edge incisor position. Full retrusion of the mandible eliminates some of the apparent prognathism of the mandible. On closure at the fully retruded position, the incisors contact and the mandible is displaced forward to the position of habitual occlusion. Some workers have claimed this occurs with rotational overclosure of the mandible to produce a deep reverse overbite. This case supports such a conclusion although not all patients of this general type exhibit as dramatic a displacement of the mandible. In day-to-day function the patient does not close in the retruded edge-to-edge position. Proprioceptive patterns guide the mandible from the open position directly to the position of maximum occlusal contact or centric occlusion.

This patient was simply treated with an upper removable appliance with a full occlusal bite plane. The four upper incisors were moved forward with individual piston screws until they were clear of the the lower incisors in the fully retruded position. A new retention appliance was then constructed without any bite plane until the posterior occlusion had settled. About 6 months later the appliance was discontinued and retention was provided by the overbite. Post-treatment checks included the mobility of the upper incisors to ensure they were not being traumatised by the anterior bite.

Occasionally the Type II case may display a very severe skeletal prognathism and orthodontic treatment will be unable to compensate for the antero-posterior discrepancy between the upper and lower dental arches. If orthodontic treatment only is attempted, the result may be excessive and unsightly lingual tipping of the lower incisors in particular. Furthermore excessive tipping is likely to impinge against the natural position of the tongue which then causes relapse. Lingual tipping of the lower incisors should be limited. If lower extractions have been done, it is highly likely there will be considerable residual extraction space. The most obvious solution to the severe skeletal problem will be a combination of orthodontics and orthognathic surgery.

The next case (Figs. 5 and 6 - RT) shows the classical Type I or divergent skeletal pattern. The mandibular plane angle is very high at 48 degrees and the gonial angle of the mandible is very obtuse giving the mandible the appearance of being almost straight from condyle to pogonion. The lower face height is excessive at 60 degrees and the ratio of posterior to anterior facial height is well below the average because of the very excessive anterior face height measurement from nasion to menton. The excessive retroclination of the lower incisors is a compensation for the severe skeletal pattern.

Given the shape of the mandible, the facial angle and the pogonion to nasion vertical values are not extreme. The malocclusion is complicated by the marked retrusion

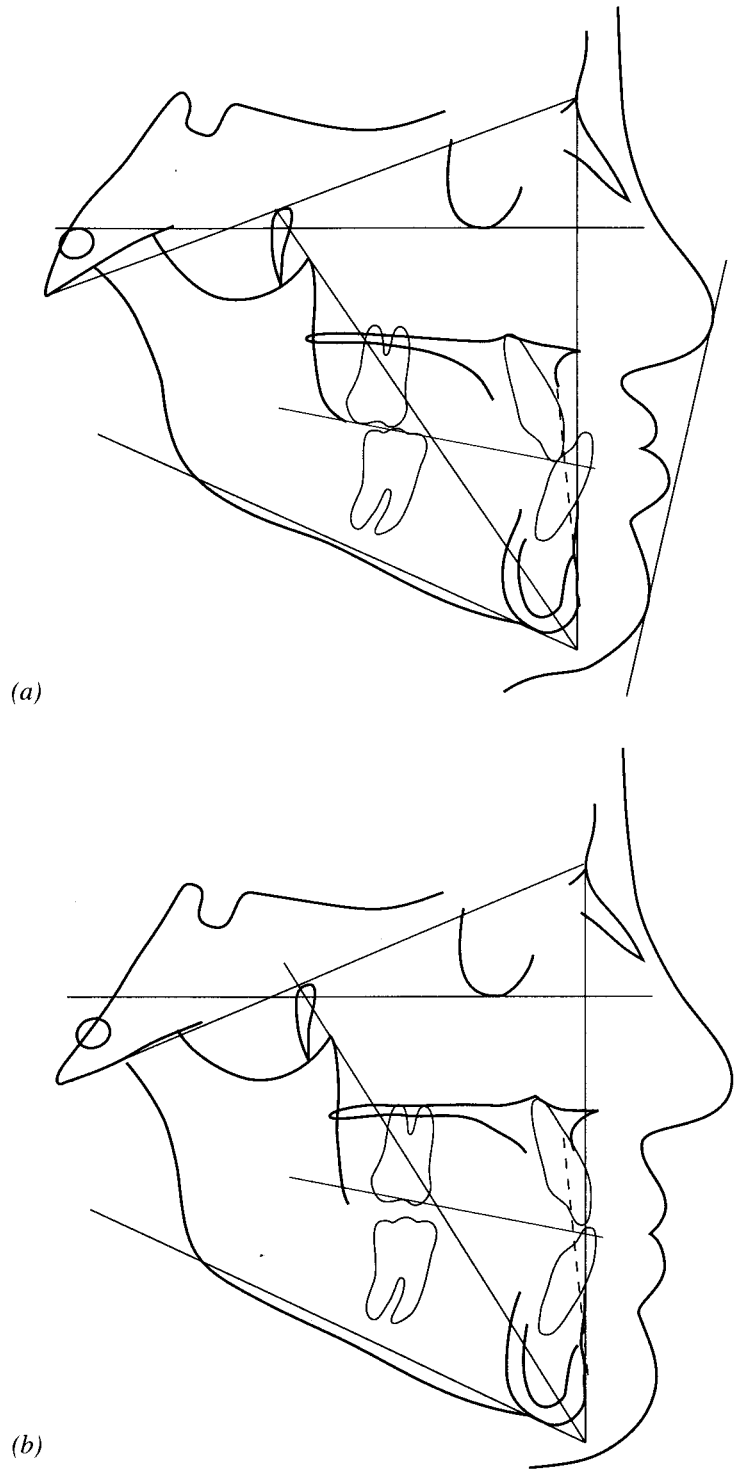


Fig. 4: Class III malocclusion (Type II convergent) (a) cephalogram taken in centric occlusion (b) cephalogram taken in fully retruded position of the mandible (same case as shown in Fig. 3).

must be taken to ensure that adequate retention is undertaken until the posterior occlusion settles and the upper incisors are not immediately subjected to the full load of the occlusion.

Of particular interest in this case is the cephalogram taken in the fully retruded position of the mandible (Fig. 4). The patient is able to retract the mandible to an edge-to-edge incisor position. Full retrusion of the mandible eliminates some of the apparent prognathism of the mandible. On closure at the fully retruded position, the incisors contact and the mandible is displaced forward to the position of habitual occlusion. Some workers have claimed this occurs with rotational overclosure of the mandible to produce a deep reverse overbite. This case supports such a conclusion although not all patients of this general type exhibit as dramatic a displacement of the mandible. In day-to-day function the patient does not close in the retruded edge-to-edge position. Proprioceptive patterns guide the mandible from the open position directly to the position of maximum occlusal contact or centric occlusion.

This patient was simply treated with an upper removable appliance with a full occlusal bite plane. The four upper incisors were moved forward with individual piston screws until they were clear of the the lower incisors in the fully retruded position. A new retention appliance was then constructed without any bite plane until the posterior occlusion had settled. About 6 months later the appliance was discontinued and retention was provided by the overbite. Post-treatment checks included the mobility of the upper incisors to ensure they were not being traumatised by the anterior bite.

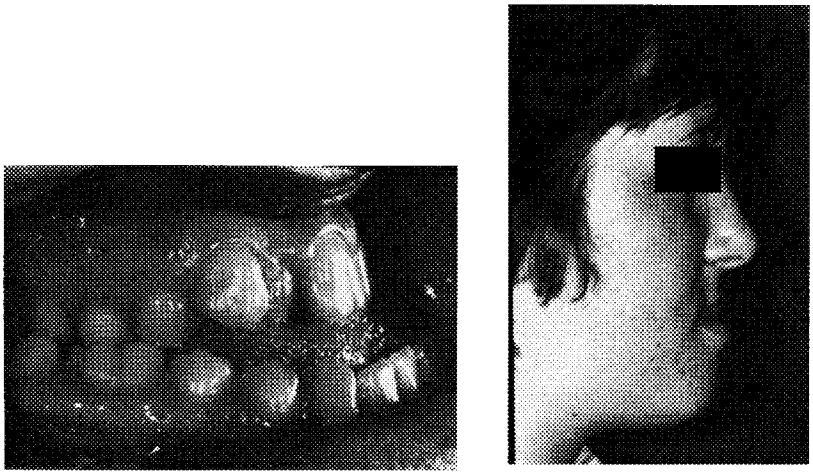
Occasionally the Type II case may display a very severe skeletal prognathism and orthodontic treatment will be unable to compensate for the antero-posterior discrepancy between the upper and lower dental arches. If orthodontic treatment only is attempted, the result may be excessive and unsightly lingual tipping of the lower incisors in particular. Furthermore excessive tipping is likely to impinge against the natural position of the tongue which then causes relapse. Lingual tipping of the lower incisors should be limited. If lower extractions have been done, it is highly likely there will be considerable residual extraction space. The most obvious solution to the severe skeletal problem will be a combination of orthodontics and orthognathic surgery.

The next case (Figs. 5 and 6 - RT) shows the classical Type I or divergent skeletal pattern. The mandibular plane angle is very high at 48 degrees and the gonial angle of the mandible is very obtuse giving the mandible the appearance of being almost straight from condyle to pogonion. The lower face height is excessive at 60 degrees and the ratio of posterior to anterior facial height is well below the average because of the very excessive anterior face height measurement from nasion to menton. The excessive retroclination of the lower incisors is a compensation for the severe skeletal pattern.

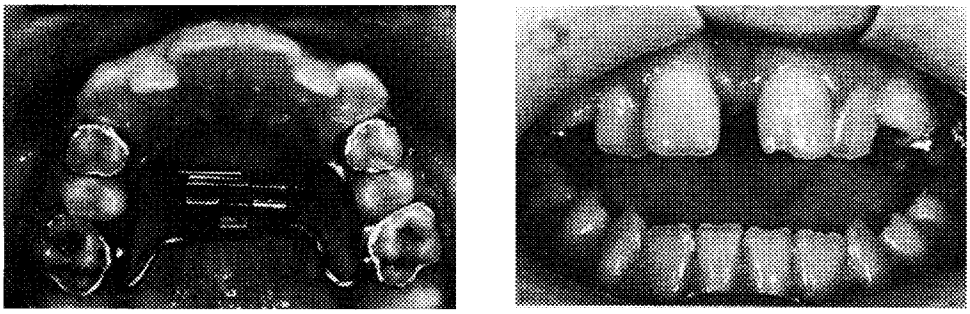
Given the shape of the mandible, the facial angle and the pogonion to nasion vertical values are not extreme. The malocclusion is complicated by the marked retrusion

(Case RT)

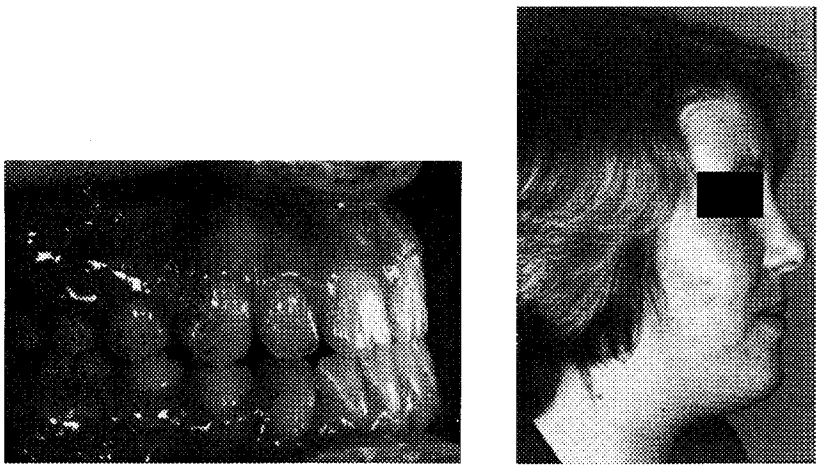
SNA	69°	MPA	48°	APt Nav	-10 mm	MxIFHP	118°
SNB	78°	F Angle	90°	PoNav	0 mm	MdIMP	65°
ANB	-9°	F Axis	80°	P/AFHt(.75)	0.46	IIA	129°
Wits	22 mm	LFHt	60°	LLEL	0 mm	MdIAPo	+10 mm



(a) (b)



(c) (d)



(e) (f)

Fig. 5: (a,b) Pre-treatment records of a divergent type of Class III malocclusion (c,d) rapid maxillary expansion (e,f) post-treatment records after orthognathic surgery.

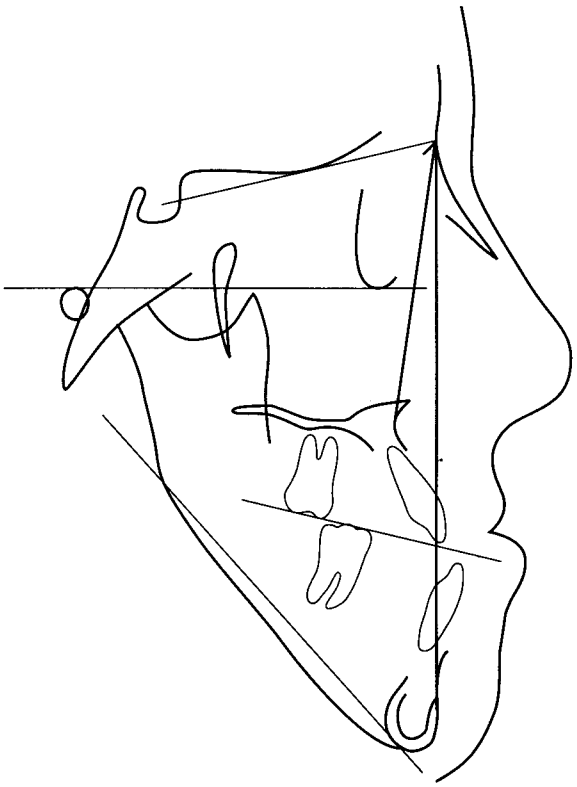


Fig. 6: Pre-treatment tracing of same case shown in Fig. 5.

of the maxillary skeletal base as reflected in the SNA value of 69 degrees with an ANB difference of -9 degrees. This is further confirmed by the Wits measurement of 22mm. The dento-skeletal development has been unable to compensate for the excessive anterior face height with a resultant anterior open bite. As often is the case, the facial appearance of these patients is not markedly unaesthetic and the anomaly becomes more apparent when looking at the occlusion and the cephalogram. There is contraction of the upper arch with bilateral buccal crossbite, anterior open bite and reverse overjet.

Clearly the treatment of such a case is beyond the capacities of orthodontics alone. There is a need for combined orthodontic treatment and orthognathic surgery. The first stage involved maxillary bilateral expansion with a rapid maxillary expansion device. Note the large diastema which has opened between the upper central incisors as the fixed screw was opened at the rate of one quarter of a turn each day for three weeks. The diastema closes naturally under the pull of the stretched inter-dental fibres during the next stage of treatment.

Orthodontic treatment normally will be directed to arch alignment and incisor decompensation, usually with uprighting of the lower incisors. Upper arch extractions may be required to overcome the crowding and to align the upper arch. In this case no upper arch extractions were undertaken. At the end of orthodontic treatment, the

arches should be aligned and coordinated for width so that at the time of surgery the surgeon is able to fit the lower and upper arches together in their new positions. Orthognathic surgery in this case involved down-fracture of the maxilla which was then protracted and impacted posteriorly to allow correction of the mandible in association with the osteotomy of the lower jaw. Surgical management was complicated by the narrow antero-posterior width of the ramus. Such a bimaxillary procedure provides a more predictable esthetic outcome allowing skeletal basal improvement in the positions of both the upper and lower jaws.

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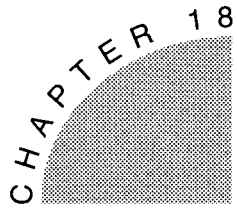
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FUNCTIONAL APPLIANCES

The term functional appliance refers to any appliance which utilises one or more of the groups of circum-oral and cranio-facial muscles. The original concept of their action was environmental modification leading to optimal bone growth. There are many such appliances although in recent years the term has become closely identified with those appliances used to correct retrognathia. Unfortunately the effectiveness of functional appliances has been obscured by the arguments concerning their mode of action. There is no doubt that they are able to achieve impressive changes in the spatial relationships of the upper and lower dental arches in carefully selected cases of retrognathia. The main point of contention is whether they are capable of inducing condylar growth which leads to an increased length of the mandible thereby providing a result which cannot be attained with other orthodontic appliances.

However, uncertainty regarding the mode of action should not distract the clinician from the fact that the functional appliance, by relatively simple means, is capable of inducing changes which are very difficult to emulate with conventional fixed appliances or headgear. Nor should it be forgotten that functional appliances may be employed to great advantage prior to or even in conjunction with fixed appliances. Finally they may also be used as retainers after treatment in order to positively maintain a corrected occlusion which may be subject to the effects of unfavourable post-treatment growth. While the correction of buccal segment relationships in brachyfacial types is likely to remain stable after treatment, in dolichofacial types with a more vertical or divergent skeletal pattern, post-treatment growth often leads to slippage of the buccal segment relationships in spite of their previous correction. Retention with a slightly active functional retainer can be a significant help in the latter types.

One of the significant advantages of functional appliances in general is that they almost never cause iatrogenic damage to the teeth or the periodontal structures. The force they apply is self limiting and the nature of their contact with the teeth makes it highly unlikely that they will pose a direct threat to either hard or soft tissues. While there have been some questions raised about their longterm effects on the temporo-mandibular joint, there is no direct or indirect evidence to support the view that the joint is adversley affected. In contrast the absence of dysfunction in the many thousands of cases treated with functional appliances suggests that this is not an issue in the developing young patient.

Simple functional appliances include the anterior bite platform, the mandibular inclined plane and the oral screen. The anterior bite platform is constructed on an upper removable appliance to occlude with the lower six anterior teeth in actively

growing patients. It props open the posterior teeth and prevents posterior contact eventually leading to over-eruption of the posterior teeth and opening of the overbite. Such an effect will relapse unless the incisor relationships are subsequently altered. The mandibular inclined plane is a wedge of acrylic formed to fit over the lower incisors and acting as wedge activated by the masticatory muscles which push the upper teeth forward. It is usually designed to move one or two teeth labially. It can be particularly effective although has been replaced by less functionally obtrusive appliances which use directly controlled forces from springs or screws. The oral screen is one of the earliest functional appliances and consists of an acrylic curtain which sits in the bucco-labial vestibular space and is activated by the bucco-labial musculature. It has been used to reduce the overjet in highly selected cases with anterior spacing. It has also been used as a deterrent to thumb sucking. Its use in patients with nasal airway obstruction is obviously contraindicated. The oral screen has largely been replaced by more specifically directed appliances. Its use has also declined with the reduced popularity of myofunctional therapy.

Functional appliances for the correction of inter-arch relationships vary in design from simple forms made from acrylic to very complicated types incorporating wire skeletons and acrylic pads. In essence all rely on muscular force for their action. Discussion here will be limited in principle to those types which are designed to correct a retro-position of the lower arch relative to the upper arch. However it should be recognised that other types have been designed to correct reverse overjet but their use has not been widespread. Interestingly there is not the same enthusiasm in favour of the concept of supression of condylar growth in prognathic cases as there is in support of the enhancement of condylar growth in retrognathic cases.

Advantages of functional appliances
1. Allow simple correction of severe retrognathia in selected cases
2. Require less complex appliance skills from the clinician
3. Are very unlikely to induce iatrogenic damage
4. Chairside time and appointment frequency are reduced
5. May aid in the correction of associated habits

Disadvantages of functional appliances
1. Cannot control individual tooth alignment
2. May induce lower incisor proclination and crowding
3. Not recommended in excessive vertical dimension cases
4. Not as effective in non-growing individuals
5. Airway problems may cause difficulties with some appliances
6. Costs associated with loss or breakage are significant
7. Exfoliation requires considerable modification in mixed dentition
8. Totally reliant on patient cooperation

Orton (1990) contrasted the strengths and weaknesses of various appliances (Table 1). The value of such a table is to remind clinicians that all appliances have significant

weaknesses and a combination of mechano-therapies is frequently required in the more severe cases.

	Edgewise fixed appliance	Modern removable appliance	Functional appliance
Individual tooth positioning	Excellent	Poor	Poor
Torquing	Good-average	Poor	Poor
Arch formation	Good-average	Average-poor	Average
Intercuspation	Average-poor	Average-poor	Average
Lateral expansion	Average-poor	Excellent	Good-average
En-masse movement	Average-poor	Excellent-good + headgear	Good + headgear
Saggital arch correction	Average-poor	Good + headgear	Excellent-good
Vertical maxillary control	Average-poor	Excellent-good + headgear	Excellent-good (correct system)
Avoidance of gingival and root morbidity	Average-poor	Good-average	Excellent

Table 1: Comparison of the strengths and weaknesses of fixed, removable and functional appliances (Orton, 1990).

GROWTH

The effects of functional appliances in the correction of retrognathia are more easily achieved in the growing patient and in very general terms it is desirable to treat suitable cases in the prepuberal period. While the estimation of the peak growth velocity at puberty is conceptually important to understanding the timing of growth, it should not be forgotten that virtually all prepubescent children are still growing at a relatively high rate and treatment of retrognathic problems with functional appliances should be commenced well before peak puberal velocity. Difficulties may arise from the exfoliation of deciduous teeth but the positive benefits of treating severe problems in the mixed dentition should always guide the clinician. Experience also shows that children at this stage of development have few practical or social problems in wearing what appear to be cumbersome devices and the results are frequently dramatic. However, case selection is all important. Once growth begins to decline the clinician is often faced with a dilemma. The decline in growth parallels a change in social patterns, often with lower compliance rates. Should the clinician maximise the benefits of any remaining growth by using other methods which are less dependent on patient compliance? This is often a difficult decision because significant changes with functional appliances may still be obtained in the adolecent patient providing cooperation is very good. Unfortunately, sexual maturation and enthusiastic cooperation are often incompatible.

ACTIVATORS

The traditional functional appliance is a monobloc, characterised by a one-piece construction designed to engage the upper and lower arches at the same time. There is no intrinsic force system and it is constructed to a protrusive functional or working bite and generally employed in the correction of retrognathic malocclusions. The mandible is positioned forward to or near an edge to edge bite of the incisors, making sure that the centre lines are coincident (Fig. 1).

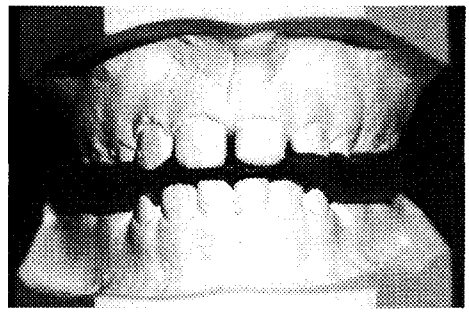
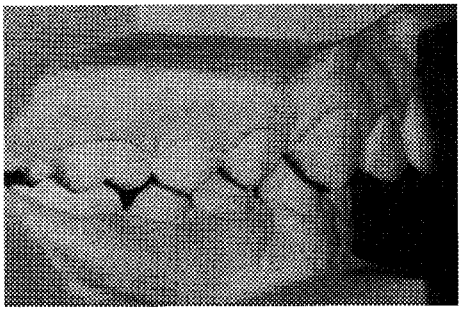


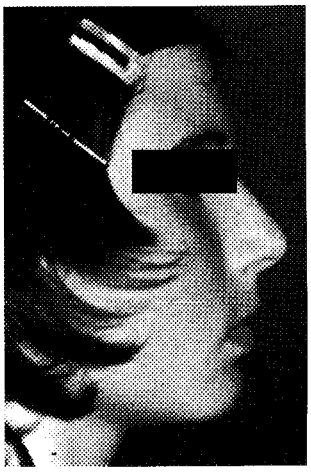
Fig. 1: Models positions in protrusive wax working bite prior to construction of functional appliance.

The amount of bite opening is varied according to objectives and design factors such as the need to cap the incisors but usually the vertical space between the upper and lower incisors is set at 3 – 4 millimetres. The amount of protrusion established in the working bite is limited to an amount which can be comfortably achieved by the patient – usually about 6 – 8 mm. Where the overjet is excessive two appliances may be required to achieve complete correction. DeVincenzo and Winn (1989) found little difference between the results of treatment of Class II malocclusions with appliances constructed to a limited protrusive bite as opposed to a single large saggital advancement. Patient comfort and mobility would seem to be more important practical determinants of the extent of the protrusive bite and the amount of inter-occlusal clearance.

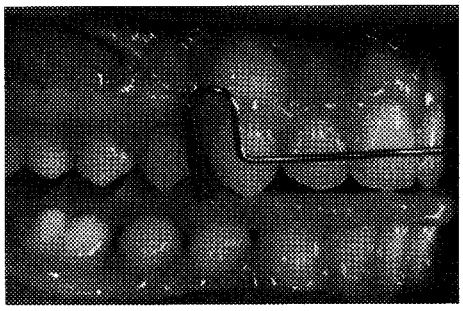
One of the earliest and most widely used monobloc appliances was the Andresen activator. While many modifications have been devised the original design continues to be used effectively. The corrective action of the activator comes from two mechanisms. The forward bite activates the stretch reflex in the sling muscles supporting and controlling the mandible such that the muscles activate the appliance by trying to return to their resting lengths. This in turn transmits force and eruptive guidance from the lower dento-alveolar structures to the upper dento-alveolar structures. In the growing individual there is restraint of forward maxillary development. Some corrective effects may also come from accelerated growth of the condyles when they are distracted from the condylar fossae leading to a small gain in length of the mandible but ultimately not more than the genetically controlled potential of the individual.



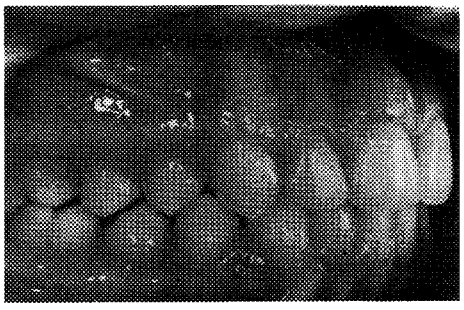
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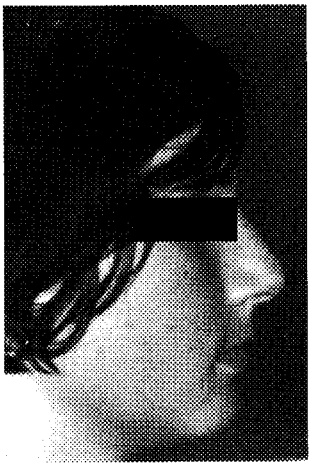
(b)



(c)



(d)



(e)

Fig. 2: (a,b) Pre-treatment records (c) functional appliance showing trimmed acrylic in buccal segments (d,e) interim records of case treated with the functional appliance.

The acrylic fitting surfaces against the teeth may be trimmed to induce simultaneous occlusal and buccal movements of the teeth in the lateral segments (Fig. 2). Selective trimming of the upper buccal sections only may help to correct a crossbite tendency

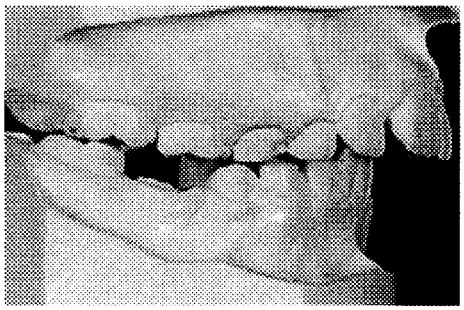
caused by the forward bite of the mandible. Trimming the occlusal facets may also help to eliminate the lateral openbite which almost invariably results during treatment and subsequently closes down. Another problem arises as the mandible is protruded into the functional protrusive position. Lateral coordination of the upper and lower arches may be lost and cause a crossbite. Various designs have incorporated lateral expansion screws to selectively expand the arches. However selective expansion of either arch is difficult with one-piece appliances. More recently the twin block appliance has overcome this difficulty because it consists of discrete upper and lower components.

The activator most efficiently achieves good results in Class II division 1 malocclusions where the upper and lower dental arches are individually well aligned. While accessory springs and wires may be added these cannot be expected to correct rotations or control axial inclinations of individual teeth. The activator may give improvement in a range of disto-occlusion types but its most dramatic effects are seen in brachyfacial types with strong forward growth of the mandible. The activator also offers a useful adjunctive stage of treatment where major corrections of the antero-posterior discrepancy are achieved with the activator and completed with full fixed appliances, with or without extractions. The initial correction of the retrognathic arch relationship allows the clinician to undertake extractions in some cases where conventional extraction treatment with fixed appliances might fail. As with all other orthodontic treatment, patient cooperation is an important ingredient of success and unless the patient wears the appliance for at least 14 – 16 hours each day, the amount of correction will be unpredictable and any correction that is obtained on an intermittent basis is likely to be lost if cooperation deteriorates.

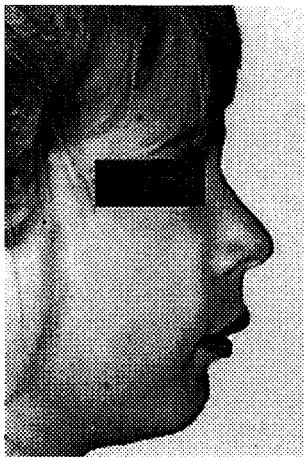
DeVincenzo (1991) studied the longterm effects of functional appliance treatment on the growth of the condyle and the ultimate length of the mandible in comparison with control patients. Of particular interest was his finding that during treatment the functional appliance did cause an accelerated growth response in the condyle but continued post-treatment monitoring showed that by the end of the growth phase there was little difference between the functional patients and the non-functional controls in mandibular length. However, the resultant changes in arch relationships are well documented.

The mode of action of functional appliances results from a variable combination of dento-alveolar modification with lingual tipping and some elongation of the upper incisors and proclination of the lower incisors, restraint of maxillary forward development and accelerated growth of the mandibular corpus but not beyond that seen in equivalent untreated control subjects. Careful case selection and good cooperation can yield surprisingly rapid correction of severe retrognathic problems. This is particularly true in the brachyfacial Class II malocclusion with a convergent low angle skeletal pattern and usually a strong symphyseal outline. The expected growth direction in such cases is more horizontal than normal. The use of functional appliances in Class II cases with crowded and proclined lower incisors could be

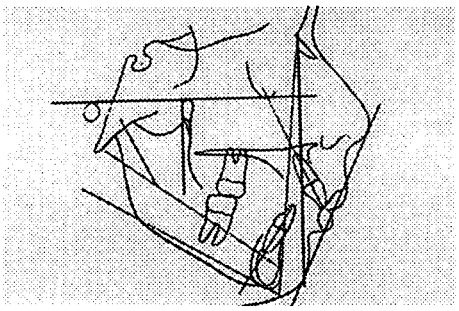
expected to exacerbate the crowding problem. While there are no absolute rules regarding the use of functional appliances, as the patient's skeletal pattern becomes more dolichofacial or divergent and the crowding increases, the side effects of the appliance could be expected to be disadvantageous. However, even in this type of case the operator may decide to obtain initial correction by means of the activator to be followed by detailing with fixed appliances (Fig. 3, 4).



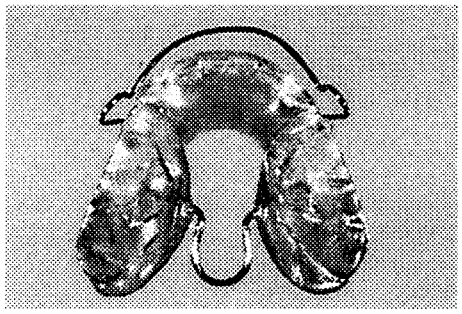
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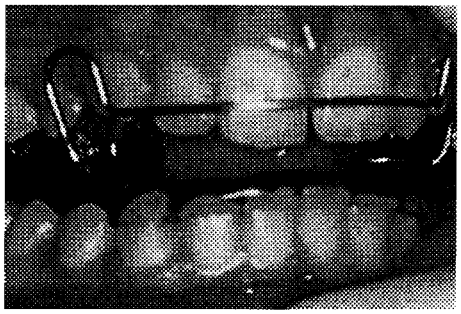
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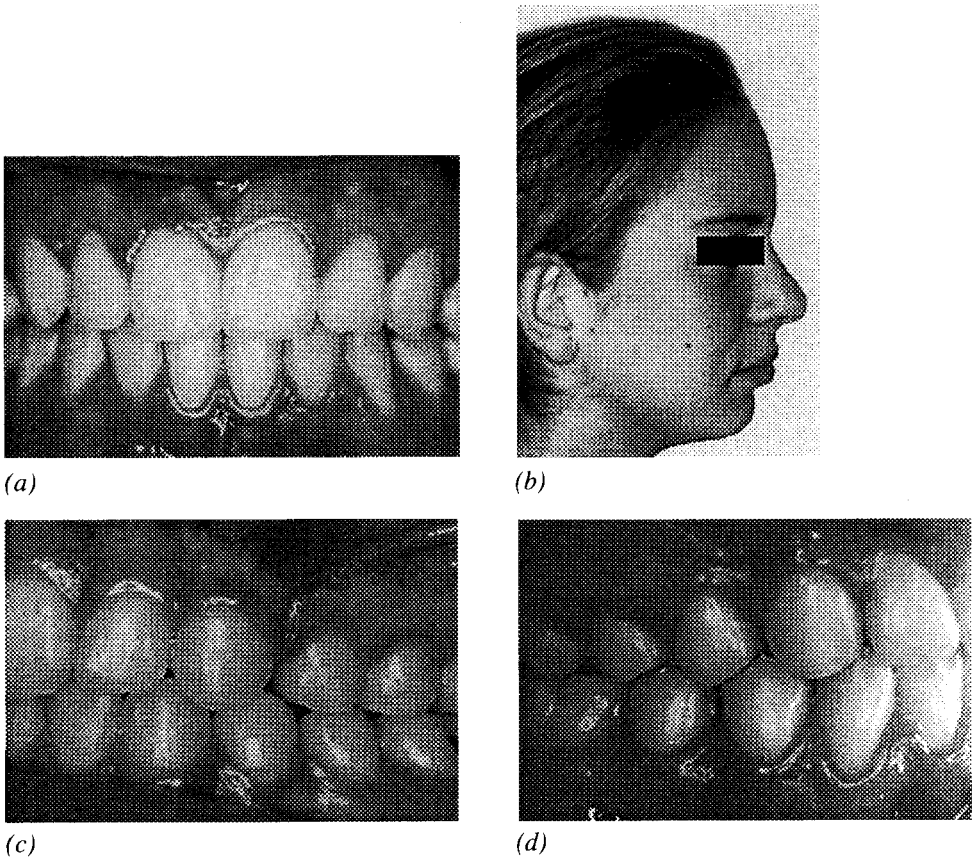


(d)



(e)

Fig. 3: (a-c) Pre-treatment records (d) appliance used (e) appliance in place showing lower incisor capping.



(a) (b)

(c) (d)

Fig. 4: (a-d) Post-treatment records of same case shown in Fig. 3 – treatment included a functional appliance followed by fixed appliances.

Modifications of the original Andresen design are legion and most tend to be a variation of the same theme. One of the earliest modifications suggested was an opening in the acrylic behind the six upper anterior teeth for the purposes of creating an open airway for respiration in children who might have nasal air ways problems due to chronic rhinitis or the more transitory effects of the common cold (Fig. 5).

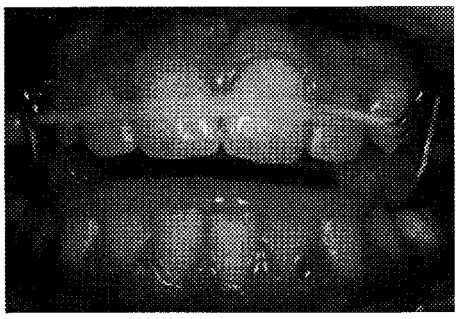
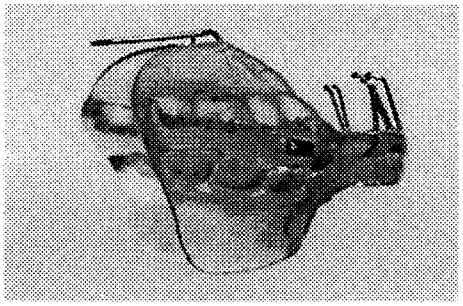
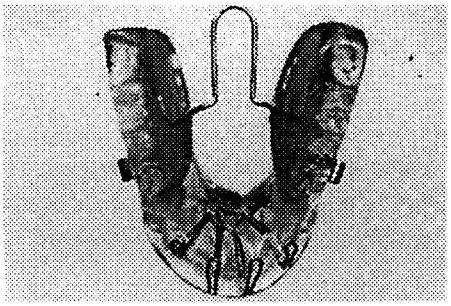


Fig. 5: Modified Andresen appliance with acrylic removed behind the upper incisors, elastic to retract the upper incisors and Sved capping over the lower incisors.

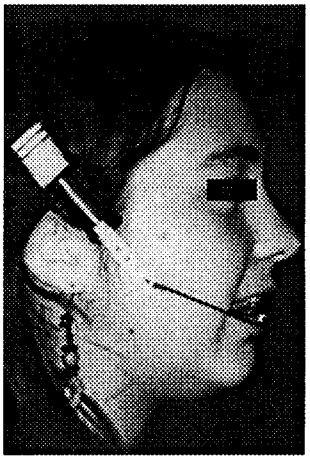
Another activator design modification was proposed by Teuscher (1978) who incorporated a headgear (Fig. 6). The headgear is of the high pull type and provides vertical control of the dentition and is more suitable in cases with a dolichofacial tendency where anterior bite opening is to be guarded against. The lower incisors may be further controlled by covering them with a Sved capping to limit tipping. Torque springs to the upper incisors may also be incorporated where lingual tipping during retraction is to be minimised. If the upper incisors are proclined prior to treatment, a conventional labial bow may be used instead thus allowing lingual tipping as the teeth are retracted.



(a)



(b)



(c)

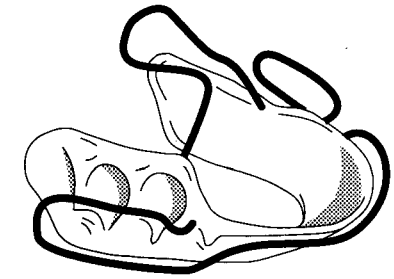
Fig. 6: (a,b) Teuscher appliance with incisor torquing springs and headgear tubes (c) high pull headgear of the type which may be added to the appliance.

The philosophy of dental orthopedics which advocates a procedure of functional correction plus ad libitum arch expansion to overcome crowding is not supported by any of the current scientific literature. These techniques are favoured by some clinicians who believe that optimal development may be stimulated by expansion appliances but fail to heed the evidence of research. Most importantly from the patient's viewpoint, the opportunities and enthusiasm for orthodontic treatment are not inexhaustible and therefore failed treatment is not easily corrected. The average patient has the dedication to undertake active treatment over a period of about twenty-four months.

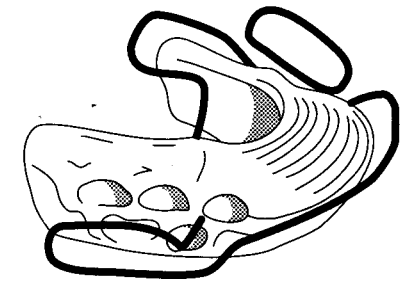
BIONATOR

The Balters bionator is a relatively elegant functional appliance with minimal acrylic bulk and incorporating a wire palatal frame and a wire vestibular guard or buccinator loop. The appliance is activated in the traditional manner with a forward functional bite. Unlike the Andresen appliance, with the bionator there is no inter-occlusal coverage of the first permanent molars which are left free to develop vertically and buccally into the field of reduced muscular pressure produced by the buccinator loops. The lower incisors may be capped to prevent tilting and over-eruption. Variants of this appliance incorporate features of the Andresen appliance with a labial bow rather than a buccinator loop and with occlusal coverage of the molars.

The palatal arch is constructed from 1.2 stainless steel wire and joins the buccal sections across the palate lying about 1mm clear of the mucosa. The purpose of the palatal arch is to stabilise the appliance. The buccinator loop section is constructed from 0.9 mm stainless wire and contacts the upper incisors but lies 2 – 3mm labial to the bicuspids. The loop extends distally to the mid-buccal surface of the first permanent molar. The acrylic base is kept to a minimum to provide maximum tongue space. The occlusal surfaces of the first permanent molars are left uncovered while only the lingual half of the occlusal surfaces of the bicuspids and deciduous molars are covered. In the later stages of wear the occlusal facets can be trimmed in the manner of the Andresen appliance (Fig. 7).



(a)



(b)

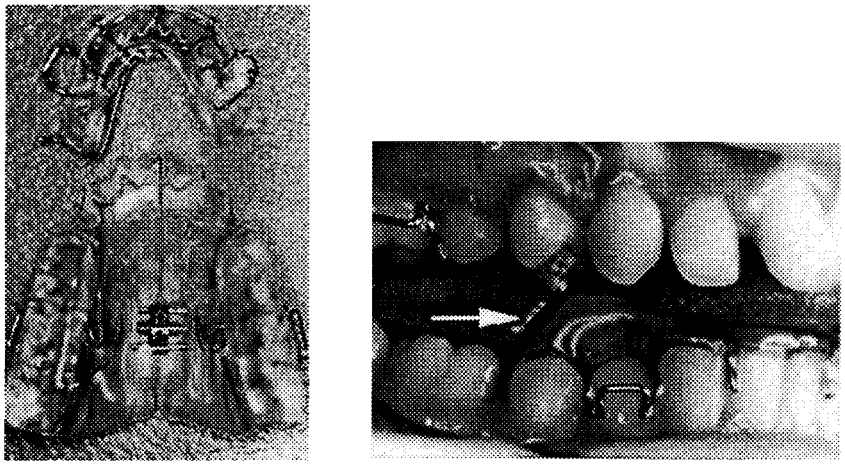
Fig. 7: (a) Bionator appliance (b) screening appliance.

Another variation of the appliance is termed the Screening Appliance and used in Class II cases with an anterior openbite or abnormal tongue function. The acrylic

behind the lower incisors is extended up behind the upper incisors to form an anterior acrylic screen to impede the tongue. This acrylic screen should not touch the teeth or mucosa but should allow natural bite closure. As a further bite closure aid, there is occlusal coverage of all the posterior teeth and this is left untrimmed.

TWIN BLOCK

One of the more recent developments in functional activators is the twin block. This appliance operates on the same principle as the Andresen appliance but consists of separate upper and lower components which occlude on a stepped bite plane – the step on the bite plane forcing the patient to bite into the active forward position. Advantages include a more manageable appliance in two parts and the ability to vary the position of the step and the amount of activation that is built into the appliance. A lateral expansion screw may also be incorporated into either component (Fig. 8). A disadvantage is that either component may be lost or broken. Retention of the upper and lower sections is achieved by conventional or modified retainers. A headgear assembly may be incorporated in the upper appliance if more vertical control is required. While eating main meals with the appliance in place is difficult, some patients are able to manage to eat smaller snacks.



(a) (b)

Fig. 8: Upper and lower components of a modified twin block appliance (b) twin block seated in the mouth and showing the stepped bite plane articulation.

In general, the more hours each day the appliance is worn the better will be the response bearing in mind that all children will take the appliance out for some school activities or sport. The appliance may be reactivated from time to time by the addition of more acrylic resin to the step interface so that more protrusion is required to bring the bite platforms together. It is surprising just how little this and monobloc appliances affect the young patient's speech. In most instances when the patient enters the surgery for a check appointment with the usual greetings, the clinician has to look carefully to see if the appliance is in the patient's mouth. The

signs of enthusiastic wear include the ability to talk clearly with the appliance in the mouth and the accumulation of calculus on the appliance. Many children will complain of being unable to 'clean' the appliance because of the accumulation of calculus. After correction of the jaw relationship, the bite blocks are progressively reduced to allow intercuspation and ultimately the lower appliance can be discarded followed later by the upper appliance, particularly if there is a need to continue a headgear.

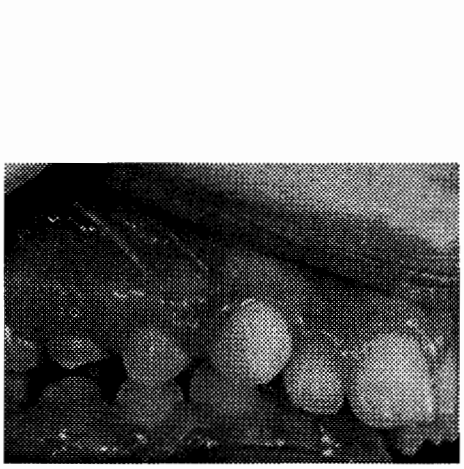
These appliances or modifications of them have also shown potential in the treatment of obstructive sleep apnoea where the mandible is held forward in the sleeping hours eliminating airway occlusion and preventing potentially dangerous low blood oxygen levels.

HERBST APPLIANCE

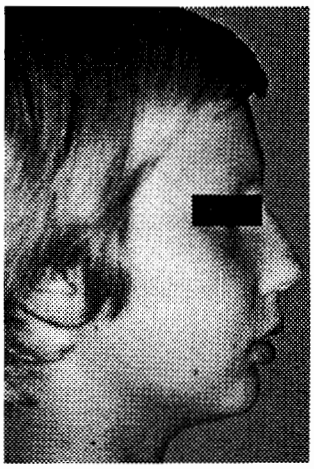
The Herbst appliance is a fixed functional appliance which supports the mandible in a forward position. The appliance was first proposed by Herbst but lapsed into disuse until rediscovered by Pancherz (1981). Early designs were fixed and could not be removed by the patient. The appliance relies on the presence of two stopped buccal pistons which hold the mandible forward (Fig. 9). Because the appliance does not rely on patient cooperation and is in place 24 hours a day, the effects can be nothing short of startling in some growing cases. As with other functional appliances the degree of mandibular advancement will be limited to a comfortable amount. The appliance is easily reactivated by adding extension rings to the buccal pistons.

A major impediment to wide use of the Herbst appliance is the high rate of breakages and cementation failure around the bands due to high loads. For this reason many design modifications have been proposed with minimal improvement in most cases. The appliance is difficult to manage clinically but for the desperate clinician, when all else fails, it may offer a solution. The appliance also causes local distortions of the occlusal plane where the pistons attach to the lower fixed structure and may cause significant depression of the first bicuspids in particular. This may be recovered in the next stage of treatment. Evidence suggests that the effects of the Herbst appliance in permanently unloading the joints rather than intermittently as in the case of other activators, may cause even more dramatic growth changes but as before the longterm results do not seem to be greater than expected (White, 1994).

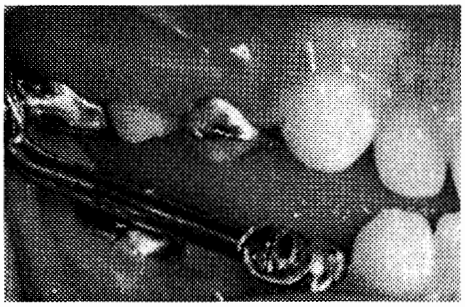
The many management difficulties associated with the appliance are reflected in the growing number of design modifications including a semi-removable type which utilises a removable lower splint to accept the piston arms. The patient is discouraged from removing the lower splint by the fact that the upper arms will hang down and impinge on the lower buccal sulcus soft tissues. Other designs utilise removable upper and lower splints allowing complete removal by the patient.



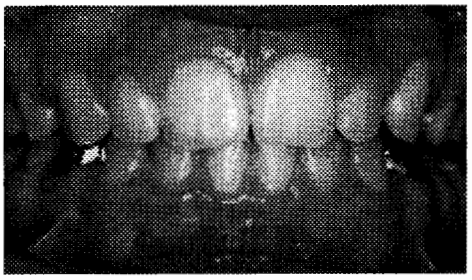
(a)



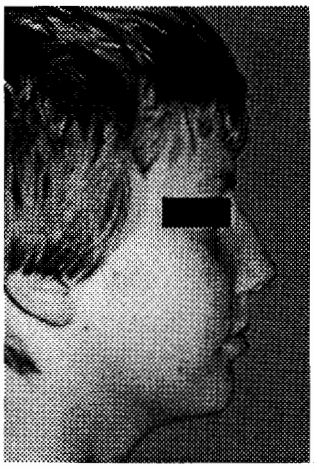
(b)



(c)



(d)



(e)

Fig. 9: (a,b) Pre-treatment records (c) Herbst appliance in place (d,e) interim records.

FRANKEL FUNCTIONAL REGULATOR

The functional regulator consists of a wire frame supporting a series of acrylic pads which hold the vestibular soft tissue away from the dento-alveolar tissues and by stretching the periosteal attachment promotes deposition of bone and optimal dento-

alveolar development. The concept underlying the actions of the appliance are complex but in essence the aim is to promote normal functional and morphological relationships which in turn promote optimal development. The theoretical background is similar to the concepts expressed in the functional matrix theory of growth expounded by Moss. The Frankel appliance is not particularly effective in the treatment of the more severe overjet problems. Some patients find the appliance difficult to wear without considerable help and instruction – in contrast to the average monobloc appliance. The appliance is useful in helping development of the occlusion during the mixed dentition and in discouraging aberrant soft tissue patterns (Fig. 10).

There are three basic designs (a) FR1 for Class I and Class II division 1 malocclusions (b) FR2 for Class II division 2 malocclusions (c) FR3 for Class III malocclusions. The appliance is relatively expensive to construct and losses and breakages cannot be borne by the clinician. What little scientific evidence is available suggests that the main lasting effects of functional regulators are again in dento-alveolar modification rather than basal growth. Nevertheless the appliance has been demonstrated to be effective although not as widely used as other functional appliances.

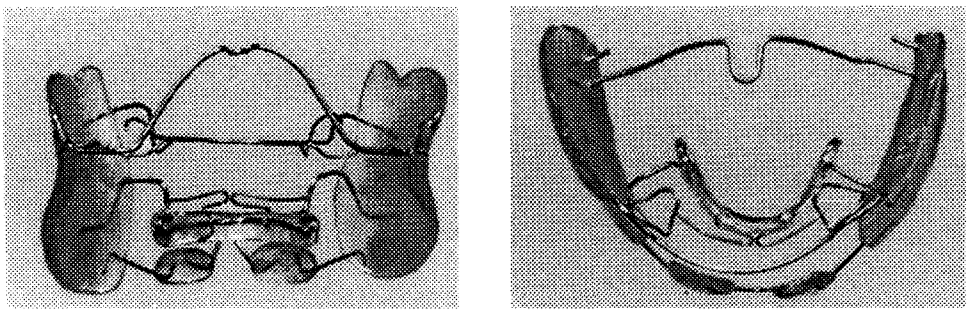


Fig. 10: Frankel functional regulator (FR1) showing vestibular acrylic pads and wire structural framework.

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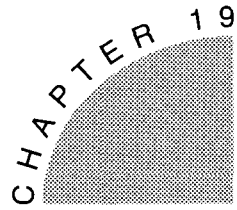
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THIRD MOLAR ASSESSMENT AND MANAGEMENT

CROWDING AND IMPACTION

The controversies regarding third molars as a cause of crowding are longstanding and the role of these teeth in late adolescent and adult lower incisor crowding has been the subject of considerable discussion and research.

Various reasons for this crowding have been proposed including:

(a) pressure from third molars which causes forward migration of the lower teeth
(b) continued growth of the mandible in the teenage and early adult years, particularly in males, so that the lower incisors become more constrained by the lips and the upper incisors leading to backward pressure with consequent lingual uprighting and crowding
(c) lack of interproximal attrition with modern diets does not compensate for the other factors such as incisor uprighting and third molar development.

Studies which do not support the role of third molars in crowding have found that crowding may still occur in the absence of third molars. On the other hand a number of studies have indicated with reasonable probability that third molars are implicated in lower incisor crowding. Late lower incisor crowding is probably due to a combination of factors acting alone or together and it is difficult to discriminate between them with any certainty. Some further evidence is available from studies of the effects of removal of second permanent molars. Their extraction dramatically alters the crowding to spacing ratio at the back of the arch providing space for eruption of the third molars and directly reducing any pressure which might be attributed to development and eruption of the third molars.

If second molars are to be extracted, there must be a reasonable expectation that the third molars will erupt satisfactorily. There are several factors which impinge on the decision to extract second permanent molars and space for third molars is only one of them. In some patients the crown morphology of the third molars may be disappointing. Upper third molars in particular may be very small compared to the second molar. This may dictate the extraction of upper third molars and lower second molars in some patients. This creates a further difficulty in that the upper second molar may over-erupt considerably while waiting for the lower third molar to erupt. Over-eruption of the second molar may cause a marked differential between the heights of the contact points of the upper second and first permanent molars. Should an interproximal restoration be required at any time it may be difficult or impossible to finish it satisfactorily.

This problem may be overcome by fitting an upper retainer with occlusal stops on the upper second molars. Some clinicians have expressed the view that extraction of second permanent molars is an undesirable procedure which should not be undertaken because of the unpredictability of the result. However, this might be considered an extreme view. Judicious extraction of second molars may be of great benefit in a small minority of patients experiencing crowding in the molar regions evidenced by progressive vertical stacking of the maxillary molars and lack of space between the lower second molar and the anterior border of the ramus. However the clinician must be reasonably confident of the eventual successful eruption of the third molars. Lawlor (1978) studied a group of patients where second molars had been recommended for extraction but only 74 per cent of the teeth were actually extracted. In the extraction group 84 per cent of third molars erupted into good occlusion. However, in the group where extractions were ignored, only 36 per cent of the third molars erupted satisfactorily. This at least suggests that the extraction of second molars in selected cases is likely to yield a successful outcome more often than waiting for eruption of the third molars.

Many patients will volunteer that they are able to feel the pressure from erupting third molars long before their appearance in the mouth or when there is no chance of their eruption. The coincidence of increasing crowding of the lower incisors and erupting lower third molars is common and strongly suggests an association between the two events in some patients at least although lower incisor crowding may still occur in the absence of third molars. Clearly the crowding of lower incisors is so common as to be classified as normal. This does not make it any more desirable. If extreme, it may become disfiguring. Where restorative procedures are required, they may be almost impossible to complete satisfactorily in the presence of marked overlapping of teeth with poor angulations.

Studies by Richardson (1989) over many years strongly suggest that third molars constitute at least one of the causes of crowding of lower incisors but the implication of third molars does not preclude the involvement of other factors. Richardson and Mills (1990) studied the effects of second molar extraction and concluded that their removal reduces the incidence of late lower incisor crowding. They also concluded that developing third molars do cause an increase in crowding in some cases. Interestingly they found that in the extraction group none of the third molars showed signs of impaction although not all had erupted at the time of examination. However in the non-extraction control group 80 percent of third molars were impacted. It is also well known that the extraction of teeth further forward in the arches, leads to a higher rate of successful eruption of third molars. Schwarze (1975) studied the effects of lower third molar germectomy and concluded that subsequent forward migration of lower first molars was significantly reduced. Lindquist and Thilander (1982) cautiously concluded that the third molars are a factor in crowding but pointed out that anatomically correct proximal contacts are also of importance in maintaining arch form. It seems to be those cases with slipped contacts that continue to crowd. This has been suggested by clinicians for many years.

Another condition has been attributed to third molar eruption. During this time there is an increased risk of TMD caused by trauma or infection of the gum flap over the erupting third molar. This causes a reflex avoidance pattern during mandibular function and induces asynchronous patterns of muscle activity. This may lead to a transitory dysfunction phenomenon.

PREVENTIVE CONSIDERATIONS

A classic work by Bowdler-Henry and Morrant (1936) assessed 633 case histories post-operatively and found complications in 121 of them, including 42 deaths. The problem was therefore a serious one, although the advent of antibiotics and better surgical and anaesthetic procedures has reduced mortality and morbidity. However, morbidity is still a problem to be considered. Possibilities are nerve damage, inferior alveolar artery damage, mandibular fracture and root tip displacement into the lingual space. In general, these difficulties become more likely with complete root formation in close proximity to the inferior alveolar canal or even the lower border of the mandible in some cases.

Stephens, Kogon and Reid (1989) addressed the issues pertaining to unnecessary removal of third molars and the scientific validity of their preventive extraction. One of the commonly cited reasons for removal is the development of a dentigerous cyst and possible transformation to other conditions such as ameloblastoma. The literature reveals a very low incidence of these conditions and the prophylactic removal of third molars for these reasons is not statistically justified. Resorption of the second molar by an impacted third molar is another possibility, but the literature suggests a very low incidence of this problem. Recurrent pericoronitis is further reason for removal of third molars but this raises the issue of whether it is justified to remove the remaining third molars at the same time, particularly where a general anaesthetic is administered. If the issue of post-surgical morbidity is considered, some would argue that the rate of about 8-10 per cent does not justify the simultaneous removal of asymptomatic teeth even when the patient is under a general anaesthetic.

However, it is important to qualify any statement on the philosophy of third molar removal by assessing the relative risks and advantages at any given age. Timing is one of the most important, yet under-rated, aspects of the art of diagnosis and treatment planning. The treatment which is correct today may be totally inappropriate next year. Orthodontic treatment in a 12 year old with a severe Class II division 2 malocclusion should have a high priority yet the same malocclusion in an adult of 30 years of age with deepbite, incisor wear and palatal stripping may have almost no chance of successful correction by means of orthodontics alone. Does this mean that because we are unable to predict the natural history of any condition, we should wait until trouble occurs and miss the most opportune time for action? Similarly with third molars, there is a stage where removal is most readily accomplished with minimisation

of the risks and inconvenience to the patient. The dentist bears a significant responsibility for advising the patient on the best course of action. Where parents and patients have been subjected to considerable inconvenience and expense in correcting a severe malocclusion, it is not acceptable or responsible to simply dismiss the third molars as being of no consequence.

Goldberg, Nemarich and Marco (1985) studied complications after surgery in 500 consecutive cases. They found complications in 7.0 per cent as follows - 4.2 per cent infection, 1.0 per cent dry socket, 1.2 per cent dyesthesia and 0.7 per cent anaesthetic complications, none of the latter being serious. Of the six cases reporting post-operative dysesthesia, five recovered and one continued to report unilateral lingual sensory loss six months after surgery. They suggested that a higher rate of nerve trauma should be anticipated if the x-rays show close proximity of the root to the inferior alveolar canal, and so the need to judge the optimum time for removal. Hinds and Frey (1980) reported the hazards associated with the retention of third molars in older persons. While the rate of these serious complications may be low, they emphasise the need to be aware of the importance of the timing of treatment. Surgery at the optimum stage minimises risks and the practitioner must weigh the advantages and disadvantages. Older persons commonly have systematic medical conditions and even in the older healthy person, surgery causes unwelcome interference in the daily routines of productive people.

Bruce, Frederickson and Small (1980) studied the relationships between age and surgical morbidity in 990 patients aged 14 to 81 years. They studied ten factors post-operatively and in every instance, the youngest group (mean age 20 years) showed a substantially lower complication rate. In addition, the mean operation time in the youngest group was about half that in patients older than 35 years. This highlights the need to qualify any discussion of the merits of third molar removal with a consideration of the age of the patient. This emphasises the need for the practitioner to monitor the development of third molars and recommend their removal, if indicated, at the optimum stage of development.

DEVELOPMENT

Estimates of congenital absence vary but one or more third molars will be congenitally absent in about 15 per cent of patients. One cannot be confident that a tooth is definitely absent until after 12 years. But commencement of development has been reported as late as 14 years of age. The following generalised remarks are directed in large part to lower third molars but apply generally to upper molars as well. Third molars begin formation at about 8 years and are seen as a small radiolucency on the x-ray quite close to the posterior aspect of the second molar. Calcification begins at about 10 years and the complete crown calcification stage is reached at about 14 years. Root formation then progresses at the rate of about 1.5mm per year and the tooth begins to erupt at the half root formation stage breaking into

the mouth at about 17 years. Root formation progresses to completion by about 20 years. Average estimates are of little help in assessing the state of development in the individual. Eruption may occur as early as 14 years in some cases and as late as 21 years in other cases. Gravely (1965) examined x-rays from 550 patients aged 6 to 15 years. Data analysis showed no significant sex differences. The earliest appearance of a third molar germ was at 7 years. Twenty five per cent had formed by age 8 years, 50 per cent by age 9 years and 75 per cent by age 12 years.

ASSESSMENT OF THIRD MOLARS

Cryer (1967) assessed the success of eruption of the third molar after extraction of the second molar at different times. The third molar eruption status was assessed as good, fair or poor. He found that the rate of successful eruption of the third molar is greater where at least the full crown stage of calcification is reached and preferably there should be some root formation prior to extraction of the second molar. Cryer showed that as the forward angle of the third molar crown becomes more pronounced, the chances of successful eruption decrease. A forward angulation of the third molar of more than 30 degrees is unfavourable (Fig. 1). Cryer concluded that in his total sample after eruption of third molars, 35 per cent were good, 40 per cent were fair and 25 per cent were poor. Notably, in those cases where the second molar was extracted after the stage of full crown formation of the third molar, the success rate increased to 70 per cent. Similarly, success rates improved where the angulation of the third molar crown was less than 30 degrees. Of interest is the finding that spacing between the distal of the erupted second molar and the unerupted third molar is likely to result in unsatisfactory eruption of the third molar if the second molar is extracted (Lawlor, 1978). Even in cases where the position of the third molar is assessed to be favourable prior to extraction of the second molar, the third molar may still erupt poorly or even become impacted.

In deciding whether or not to extract the third molar the clinician must estimate the likely amount of space that will be available for eventual eruption of the third molar. One important factor is the tooth-space ratio. The best x-ray for this assessment is the OPG (Olive and Basford, 1981a). The assessment is easily made. A line is drawn along the lower occlusal plane and perpendiculars drawn at the distal of the second molar and at the anterior border of the ramus where the occlusal plane cuts the anterior ramus outline (Fig. 1). This assessment will always err on the optimistic side, because there is an overlying layer of mucoperiosteum which will further limit the amount of useable space distal to the second molar. This can be checked by clinical examination. Olive and Basford (1981b) also showed that the medio-lateral dimension is a determinant of the liklihood of third molar impaction but is less important than the space-width ratio. As the ramus width to molar width ratio increases, the liklihood of impaction decreases (Fig. 2).

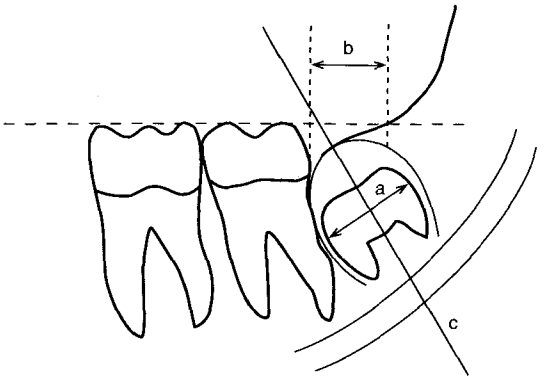


Fig. 1: Angulation of third molar crown (c) should be less than thirty degrees. The tooth-space ratio is the width of the third molar crown (a) relative to the space (b) between the distal of the second molar and the point at which the occlusal line cuts the anterior shadow of the ramus on the OPG x-ray.

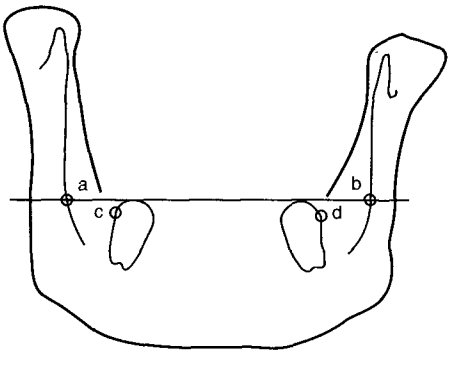


Fig. 2: The ramus-to-molar ratio is the width between the rami at the intersection of the occlusal plane and the anterior borders of the rami (a-b) relative to the width between the most lateral points on the crowns of the lower second permanent molars (c-d). (Redrawn from Olive and Basford, 1981.)

Of course one might always hope that the length of the arch will increase substantially with further growth. This is usually a hope in vain. Space behind the second molar will increase minimally after 14 years, usually no more than several millimetres. Remember that the average female is virtually finishing growth by this age. Even in males who may grow to the age of 17 years or more, the increase in available posterior arch length is minimal. However, in males the chances of eruption will continue to increase slightly. Even if the final eruption is not satisfactory, it may be sufficient to avoid extensive surgical bone removal.

In those instances where the patient has undergone a lengthy course of orthodontic treatment the orthodontist faces a considerable dilemma. Should retention of the lower arch be maintained from the end of treatment at 14 years for example until the third molars erupt or are extracted at about 17 years? Even though some studies show that not all cases will experience lower incisor crowding, other studies show that many cases do experience crowding and that there is substantial evidence to

implicate the developing third molars. It is also proven that where premolars have been extracted the chances of successful eruption of the third molars increases to about 70 percent. The non-extraction patient presents a significantly higher risk of third molar impaction. While some clinicians advocate a laissez faire approach to third molars and retention during this stage, bitter experience shows that parents and patients in this country expect more than platitudes if incisor crowding or relapse occurs in this period.

For these reasons the author has for many years adopted the principle of maintaining the lower arch with a 6-to-6 lower lingual arch in all non-extraction patients and some extraction patients until the third molars have either erupted or been removed. By this time growth will be nearly complete and continuing dental changes which have been attributed to growth will be minimised. The 6-to-6 lingual arch is a relatively trouble free retainer which requires checking only on a 12 monthly basis (Fig. 3). It is also of considerable interest that by positively holding lower arch length with a 6-to-6 retainer very few relapse problems are seen, including rotations which were present before treatment. This is in marked contrast to 3-to-3 or 4-to-4 lingual retainers, including bonded types, which allow slippage of arch contacts and loss of arch length. Bonded lingual retainers have other significant disadvantages including difficulty of removal in some cases and the 'popping' of individual teeth where the bond comes adrift. The 6-to-6 allows the clinician to accept responsibility for retention with a degree of confidence and relatively little chairside time. Occasionally, patients with a high sugar intake will be unsuitable for such a regime of retention.

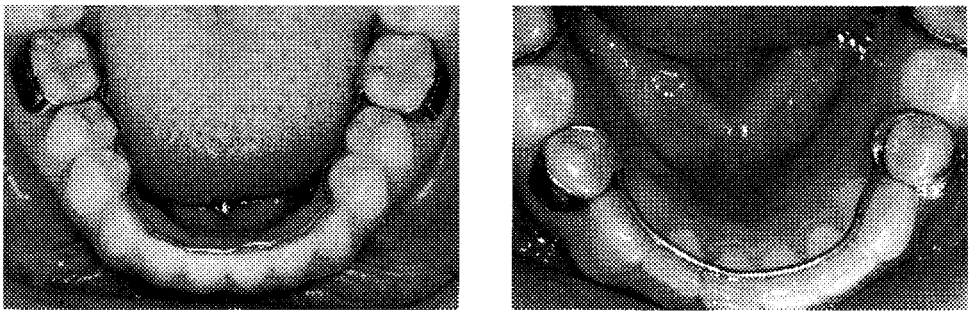


Fig. 3: (a) Lower 6-to-6 fixed retainer (b) lower 4-to-4 fixed retainer.

Another feature affecting the amount of space available is the general jaw shape. It is known that third molar impaction in Class III cases is uncommon because of the greater mandibular length. But many Class III types also have a dolichofacial tendency. Brachyfacial types have a square jaw with a square gonial angle. The relatively square jaw shape means that as the alveolus develops vertically with growth, there is little increase in posterior arch length. Olive and Basford (1981a,b) showed that there is a greater tendency to impaction in brachyfacial retrognathic types. Conversely, the dolichofacial type with a larger gonial angle and more divergent ramus shows relatively more arch length development as the alveolus develops vertically.

Most teeth begin to erupt actively at about the half root formation stage. The third molar is no different. As it begins to move it reaches a point where it has penetrated the overlying bone and the root is about two thirds completed. If the decision to extract the third molar has been made, this is the optimum time for its removal, with the undeveloped roots clear of the inferior alveolar canal. It is also an age when the patient is beginning to mature and able to cope with the rigours of surgical removal. If all other factors are favourable, and they seldom are, it is also within the optimum time range for alternative extraction of the second molar which is rarely the extraction of choice. In addition, there should be little need for space to align teeth in the anterior segments. Nor should second molars be extracted to help headgear action in the uncooperative patient. Extracting teeth won't change a patient's cooperation.

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CHAPTER 20

FIXED APPLIANCES

In properly selected cases removable appliances will give very satisfactory results. However they are effectively limited to tipping teeth in the bucco-lingual and antero-posterior directions. They are not suited to the following tooth movements – rotation, extrusion, depression, root uprighting and root torquing. Root uprighting and root torquing are similar but uprighting occurs in the mesio-distal dimension while root torquing occurs in the labio-lingual dimension. Uprighting is inherently easier than torquing because it occurs along the length of the arch wire while torquing occurs at right angles to the arch wire.

Fixed appliances are able to control and vary the centre of rotation of the tooth. This control is achieved by the simultaneous application of a simple force and compensating moment or couple at the bracket. The application of a simple single force to the labial face will tip the tooth in the same direction, around a centre of rotation at about the junction of the middle and apical thirds of the tooth (Fig. 1). The crown will move in the same direction as the force and the apex will move in the opposite direction. Root torquing requires that the centre of rotation be altered from the junction of the apical and middle thirds of the root to the attachment of the bracket to the arch wire. When this is done the length of the tooth between the bracket and apex moves in the direction of the couple and that portion of the crown between the bracket and the incisal edge moves in the opposite direction (Fig. 1). By varying the relative values of the compensating moment and the force (the moment/force ratio) the centre of rotation may be varied up and down the length of the root of the tooth. Thus tooth movement may be varied from simple tipping to controlled tipping to parallel root movement to full torque of the root.



Fig. 1: (a) Application of a simple single force causes movement around the centre of rotation (b) application of a simple force and a sufficient couple at the bracket moves the centre of rotation to the bracket.

Fixed appliances are comprised of three main components – molar tubes, brackets and archwires. While molar tubes may be directly bonded to the buccal surface of the molars, most orthodontists still use tubes welded to bands which are then

cemented onto the molars. These provide a more robust attachment in the main chewing areas of the dentition. They also overcome the difficulty often encountered in children of maintaining a strictly dry environment in the molar region, which is required for bonding. Bonding of molars in adults with easier access and control is performed more often. Bonded brackets are generally used on all other teeth anterior to the first molars. The bracket is welded to a small base with a micromesh surface on the bonding side (Fig. 2(a)). The bonding adhesive is formulated to flow into the mesh and to adhere to the prepared surface of the tooth. Different bonding adhesives require different procedures. Most are chemically activated although light activated systems are also available.

BRACKETS

The edgewise bracket has a rectangular section slot. The slot size is either .018 x .025 or .022 x .028 (inch) with the shorter side lying vertically adjacent to the face of the tooth. The siamese bracket consists of two narrow components which are separated from each other. This is equivalent to a single bracket of the same width. Edgewise brackets may also be manufactured with vertical auxiliary slots in the base of the bracket. These slots are capable of accepting auxiliary springs or they may be used to place an elastic tie as required. The slope of the buccal surfaces of the teeth varies considerably. Therefore a bracket will lie at quite different angulations on the buccal surface of different teeth. Early edgewise brackets were of a standard design and the clinician had to vary the amount of twist in the arch wire to suit the particular tooth. Modern prescription brackets are designed with in-built torque to compensate for the slope of the buccal surface of the individual tooth (Fig. 2). This variation in slope is starkly represented by the difference in the slope of the face of a lower incisor compared with the slope of the facial surface of the lower first molar. When the brackets are placed on all teeth, the bracket slots should all be at the same absolute vertical height and the floor of the bracket slot should be horizontal after alignment. Additionally, the thickness of each bracket must be adjusted to compensate for the natural in-out variations of the facial surface of the teeth. For example the upper lateral incisor labial surface is less prominent than the labial surfaces of the central incisor and the canine. Full prescription brackets will therefore compensate in all three orders of tooth movement.

The edgewise bracket slot will accept any round, square or rectangular wire up to the maximum dimension of the slot. As the wire size increases to the same dimensions as the slot, then the fit becomes more exact and a rectangular wire is unable to rotate. However, as the dimensions of the rectangular wire are reduced, the fit of the wire in the bracket becomes less exact and even the rectangular wire may rotate to a certain extent (Fig. 3). Maximum effective torque will be generated by a closely fitting arch wire. Edgewise brackets are commonly manufactured as either single or siamese types.

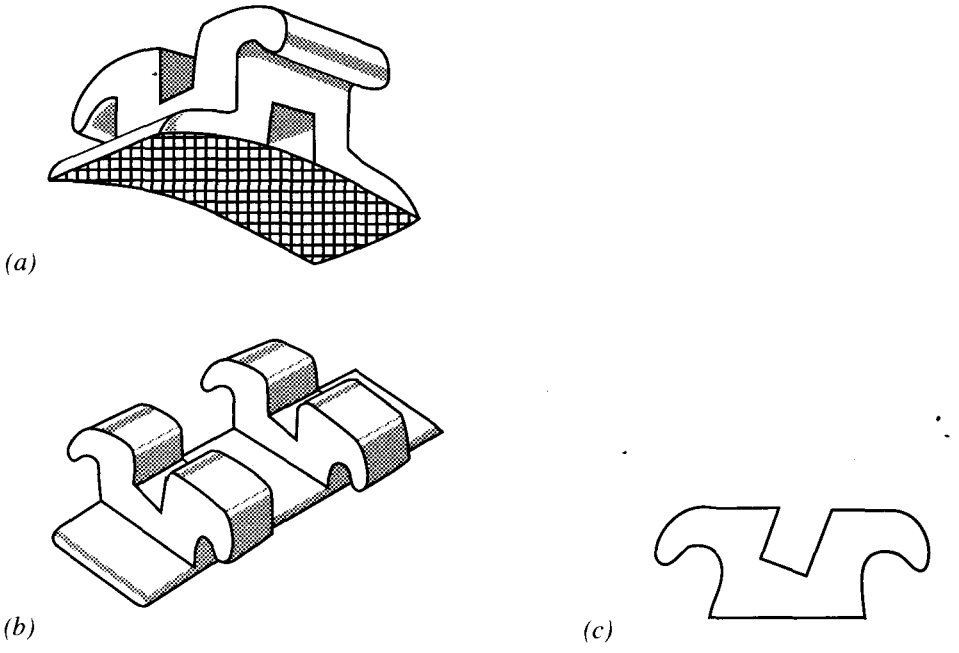


Fig. 2: (a) Edgewise bracket with micro-mesh base and integral accessory vertical slot behind the archwire slot (b) siamese bracket with two separate bracket components (c) bracket with compensating torque incorporated in the structural design of the bracket.

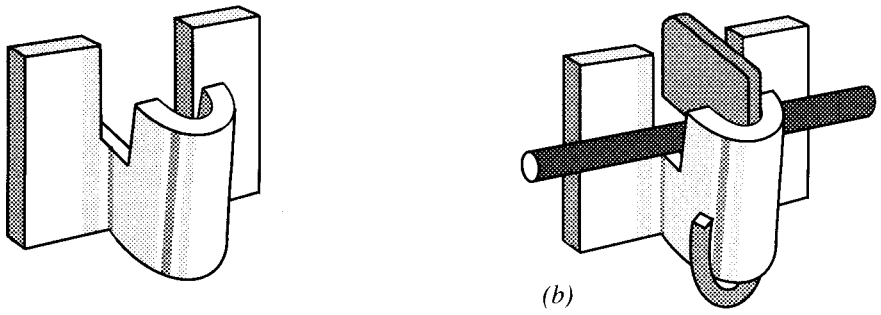


Fig. 3: (a) Edgewise slot completely filled by the archwire providing complete torque control (b) smaller dimension wire which must rotate to engage sides of slot (c) round wire provides no torque control (d) wire must be twisted to engage slot and will then torque the tooth in the opposite direction.

Theoretically, with modern prescription brackets, if each bracket is correctly positioned on the tooth, the clinician simply places a final flat rectangular arch wire in the brackets to achieve the torque and tip built into the bracket base. Unfortunately the theory will be let down by teeth of non-standard shape or by incorrect bracket placement – both relatively common occurrences. One of the disadvantages of these systems is that a different bracket is required for every tooth and great care must be used to ensure that the correct bracket is bonded to the intended tooth. Begg brackets, however, in any given case are of a single design and the main variation is between a flat base for incisors and a curved base for canines and bicuspids. Other than this limitation any Begg bracket may be placed on any tooth.

The Begg system was introduced by Raymond P Begg, an Adelaide orthodontist. The Begg bracket provides an open gingival slot with the wire being held in the slot

by means of a brass pin. The bracket is designed to allow free tipping of the tooth mesio-distally and labio-lingually. The maximum wire diameter which can be accommodated in the slot is .020 inch although most of the earlier stages of treatment are completed using an .016 inch arch wire. The heavier arch wire is used toward the end of treatment when better control is required. This bracket is unable to directly control the tooth in three dimensions. It cannot directly apply torquing or uprighting forces on the round archwire and is also limited in its control of rotation. These complex movements require the addition of auxiliary devices which form an important part of the Begg treatment system (Fig. 4). In the early stages of treatment the Begg system is conceptually simple and moves teeth very quickly by tipping movement. In the later stages treatment becomes more complicated with the application of various auxiliary devices for fine control, uprighting and torquing of tooth positions. Begg also collaborated with the metallurgist Arthur Wilcox in Melbourne who was the first to successfully develop methods for heat treating stainless wire to produce very resilient high tensile steel arch wires.



(a) (b)

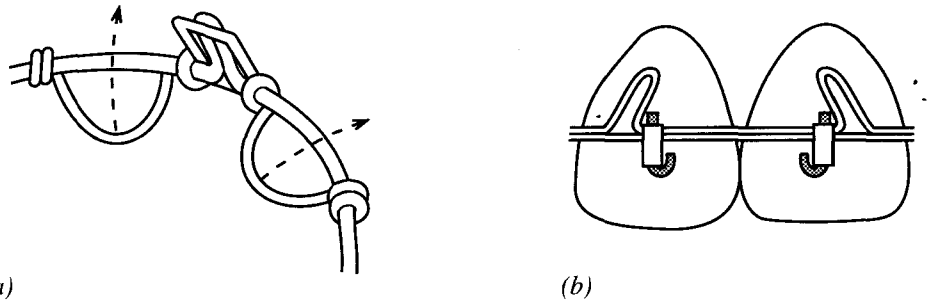
Fig. 4: (a) Begg bracket (b) Begg bracket with brass pin to secure archwire.

TORQUE

The method of application of torque to the tooth varies with different technics. The edgewise technic depends on the inherent elasticity of the main arch wire and the fit of the rectangular arch to the rectangular bracket. If the arch wire profile and the bracket slot are aligned to each other, then no torque is produced as the wire is seated in the bracket slot. As the alignment of the arch wire profile relative to the bracket slot varies, then the arch wire must be twisted or torqued to fit into the bracket. On seating the wire in the bracket slot, the natural elasticity of the arch wire becomes activated and the wire tends to twist back to its original position (Fig. 3). This induces a torque of the tooth root in the same direction in which the wire recovers.

The Begg technic depends on a different principle to achieve torque of the tooth root. This technic uses a round arch wire which fits relatively loosely in the slot in the bracket. The arch wire is inserted into the slot from the gingival direction. The round wire is not able to directly engage the bracket and therefore cannot exert a torquing moment in the same manner as the edgewise bracket. The Begg system

therefore relies on the use of an auxiliary device to apply the torquing moment. One such auxiliary is the rat trap spring which applies a force to the crown near the gingival margin. This force then rotates (torques) the whole tooth round the centre of rotation at the level of the arch wire in the bracket slot. The activation of the rat trap spring requires that it be prevented from rotating freely around the main arch. This is usually done by means of a vertical post or U loop bent into the main arch so that as the rat trap spring is raised from the passive position, it is activated against the post. Another torquing device is the spur torquing arch which is placed as an overlay sectional arch in the same bracket slots as the main arch wire (Fig. 5).



(a) (b)

Fig. 5: (a) Rat trap torquing spring which is activated against the post bent in the arch (b) torquing arch spurs – the auxiliary arch sits on top of the main arch and both are secured with brass pins.

UPRIGHTING

Uprighting with the edgewise bracket is provided by elastic deformation of the arch wire when seating the wire in the slot. The length of the slot creates reciprocal levers at the bracket edges. Wider brackets such as siamese designs will provide better axial control. The greater the tolerance between the wire size and the slot dimensions, the less will be the uprighting force (Fig. 6). Force will also be reduced by the inherently lower load-deflection rate for wires of smaller diameter which are also more flexible. Thus in the early stages of treatment where teeth are badly tipped the clinician must select a wire type and diameter which provides an acceptable balance between adaptability to the bracket, force generated, range of action, resistance to the oral environment and time between appointments. These various requirements are not always easily accommodated in patients who are careless with appliances.

The Begg bracket does not exert any inherent control over uprighting. In fact in those cases where teeth are badly tipped prior to treatment and a depressive force is applied to reduce the overbite, the axial depression force may cause a deterioration in the angulation of the tooth. This occurs because the force is applied outside the centre of resistance which creates a moment which causes further tipping (Fig. 7). In contrast this problem is overcome with the edgewise bracket, in the mesio-distal dimension at least. Uprighting with the Begg bracket must be achieved by means of auxiliary uprighting springs which are placed in the bracket tube and activated by

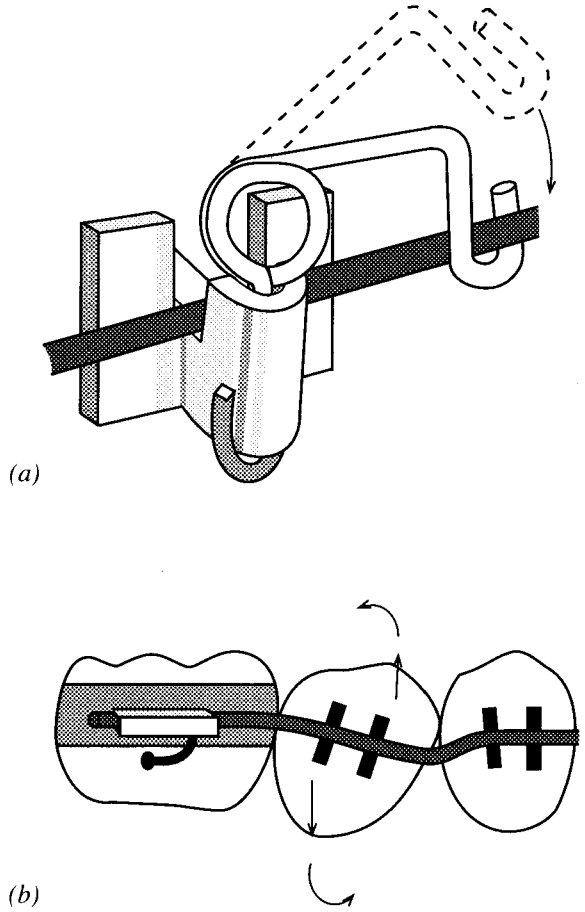


Fig. 6: (a) Uprighting spring applied to a Begg bracket (b) uprighting action with edgewise bracket occurs when archwire engages the slots due to archwire elasticity.

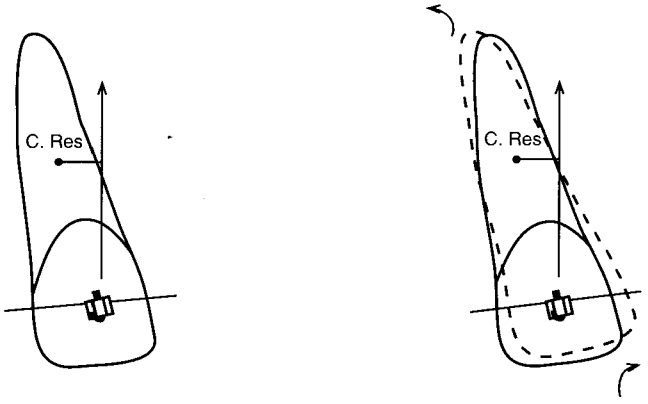


Fig. 7: (a) Depression force outside the Centre of Resistance creates a moment (b) Begg bracket allows free movement of crown with further axial rotation as the tooth depresses.

hooking on to the arch wire. Some edgewise brackets also contain vertical slots which are capable of accepting springs for uprighting.

ROTATION

Rotation of any significant amount is difficult to achieve by elastic distortion of the wire into the bracket slot although edgewise brackets are inherently more capable of correcting small rotations than is the Begg bracket. The flexibility of steel archwires for the purposes of de-rotation may be achieved by bending vertical U loops in the wire immediately adjacent to the tooth. The loops increase the flexibility of the wire in the region allowing elastic deformation of the wire into the displaced bracket. The need for such loops has declined with the advent of the low modulus nickel-titanium and braided steel archwires. However on occasions the clinician requires the relative stiffness of the conventional steel archwire for other reasons but with the added requirement of de-rotating one or two teeth. De-rotation is also dependably achieved by means of rotation springs which are inserted in the vertical slot of the bracket and activated in the horizontal plane by bending the free end into a lever arm against the crown of the tooth prior to activation by hooking over the arch wire. However, de-rotation springs may be difficult to place in cases with restricted interbracket distances, particularly in the lower incisor region. Very severe rotations will require the application of reciprocal labial and lingual forces (Fig 8). To achieve this a button or hook must be provided on the lingual of the tooth in order to apply a lingual force in the opposite direction to the buccal force. If a tooth is rotated with the buccal and lingual surfaces to the interproximal, it may be necessary to achieve some initial rotation before repositioning the attachments to complete the correction. Teeth which are corrected from significantly rotated positions may require pericision to reduce the relapse tendency.

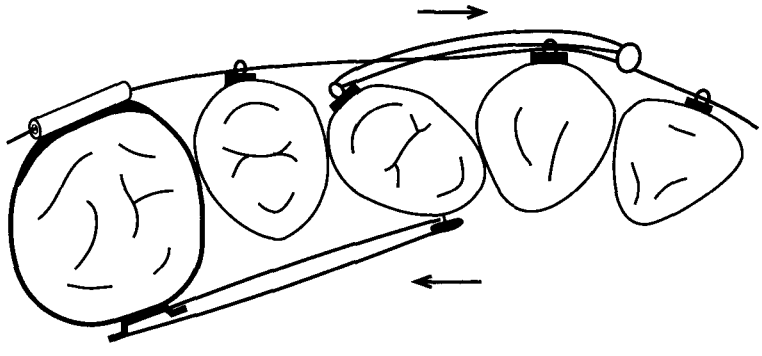
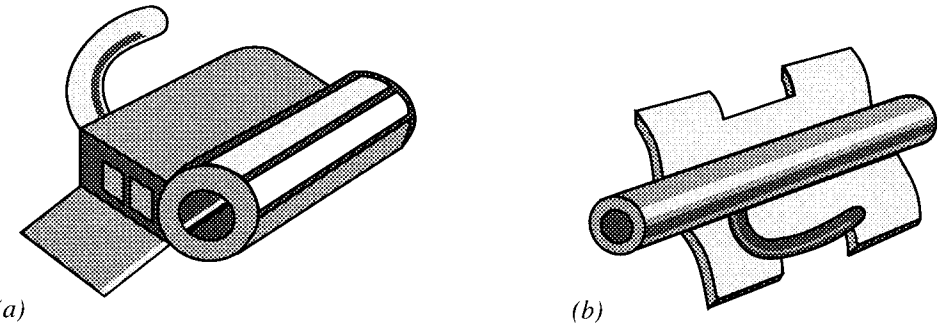


Fig. 8: Reciprocal elastic ties from buccal bracket to circle in arch wire and from lingual button to lingual cleat to rotate upper left first bicuspid.



(a) (b)

Fig. 9: (a) Upper edgewise molar assembly with two arch wire tubes and large headgear tube (b) Begg round (.036 in) molar tube with elastic hook.

MOLAR TUBES

Edgewise brackets with rectangular slots are used with matching rectangular molar tubes. Upper edgewise molar tubes are commonly designed with two arch wire tubes and a headgear tube in the one assembly. The extra archwire tube is used for auxiliary sectional or overlay arches as used in the Ricketts technic. Molar assemblies usually incorporate an elastic traction hook. While not all components are used in every case they provide the clinician with the flexibility of biomechanics without having to reband the tooth when an extra component is required. The headgear tube may lie to the occlusal or gingival aspect of the assembly. The Begg system molar tube is a round .036 inch tube usually incorporating an elastic traction hook. Headgear tubes are added to both edgewise and Begg upper molar attachments (Fig. 9). Another common attachment on molar bands is the lingual hook or cleat used for lingual elastics or for lingual inter-maxillary elastic pull to help prevent mesio-buccal molar rotation when closing extraction spaces.

PALATAL ARCHES

Simple palatal arches are used quite often in conjunction with fixed appliances. The usual design connects the palatal surfaces of the molar bands on the upper first permanent molars. Because the molars are prevented from rotating around the large conical palatal root, the palatal arch will reinforce anchorage very effectively. The Nance palatal arch is a variant which incorporates an acrylic button against the slope of the anterior palate and is used to further reinforce anchorage. A variety of removable palatal arch designs is available commercially and allow for adjustment which may be required to de-rotate a molar or widen the inter-molar width. Palatal arches are also commonly used to incorporate auxiliary spring arms in the retrieval of palatally impacted canines which often lie up behind the incisors. The first line of movement of such a tooth is distally before movement buccally into the correct position. During the phase of labial movement of the canine, the palatal arch also supplements the labio-lingual anchorage of the upper arch and prevents unwanted

reactive movement, particularly in the bicuspid region. Without the stabilising effect of the palatal arch, the biscuspid may be moved into a crossbite.

ARCH WIRES

Treatment with fixed appliances usually commences with a flexible wire which can be elastically deformed to the irregular positions of the brackets on displaced teeth. If steel is used the clinician will use a small diameter round steel wire to be followed by a series of stiffer wires. When using the edgewise appliance the later wires are rectangular and close to the bracket slot size. With the Begg technic, round wires provide most of the main arches. Rectangular wires are also considerably stiffer than the round wire equivalent. For example an .016x.016 inch rectangular steel wire is 1.7 times stiffer than a .016 inch round steel wire. The orthodontist must select the optimal stiffness, deflection and force depending on the alignment of the teeth. In the early stages of treatment smaller round wires allow adequate deflection toward the bracket without undue force.

In the early stages of the development of fixed appliances gold was used for bands and arch wires. Its use for arch wires was based on the need to control its stiffness by heat treatment. However stainless steel bands and arch wires soon provided a much more cost efficient material and the use of gold was discontinued. Stainless steel is still the most frequently used material for bands, brackets and arch wires. Wilcox's success in heat treating stainless steel provided unusually high tensile steel archwires for orthodontic treatment. However more recently a series of new nickel-titanium alloy materials has provided low modulus arch wires which are extremely elastic and can provide gentle forces over ranges which are impossible to achieve with stainless steel. These wires cannot be permanently deformed under the conditions of use in the mouth. An attractive property of these wires is their almost constant load-deflection rates after the initial activation. This means that as the wire is deformed further, the force applied to the tooth does not increase.

It is seemingly attractive to tie a low modulus wire into displaced brackets and simply wait for the teeth to move to the desired positions. Unfortunately there is much more to the biomechanics of tooth movement, particularly if extractions have been performed. There is also some concern that the unrelenting force applied over a long range by low modulus archwires may be more likely to cause root resorption. One of the benefits of stainless steel may be its limited elastic range before becoming permanently deformed. The force system is intermittent. This requires the clinician to reduce the force applied to a small range. After the tooth moves within this limit, time for repair is available before the next activation. In order to achieve root torque with stainless steel arch wires, the wire size must be increased to the internal dimensions of the bracket slot in order to engage the bracket accurately. Unfortunately these large rectangular wires are very stiff and may be very difficult to seat fully into the slot, producing very high loads. It is perhaps in these later stages of treatment

that low modulus rectangular arches of maximum dimension may offer a physiologically acceptable torquing and finishing system.

BONDING

Bonding requires that the tooth surface be thoroughly cleaned with pumice prior to etching with an acid etchant, usually with a solution of phosphoric acid. Gel etchants are more convenient than the liquid forms and enable stricter limitation of the area of etch. Teeth in patients who have received consistent fluoride supplements may be difficult to etch effectively in some cases. After etching and drying the tooth surface will show an opaque chalky area which must be literally dessicated for good bonding adhesion. A high volume evacuator will usually provide an adequately dry field. Most bonding systems require the initial placement of a low viscosity sealant between the bonding resin and the tooth surface. A particular effort should be made to remove any excess flash of resin which may appear round the edges of the bracket base as the bracket is seated on the tooth. Excess material can be very irritating to the gingivae due to the collection of plaque and debris.

The final satisfactory alignment of the teeth on an archwire requires that the brackets and tubes be positioned correctly before the commencement of treatment. The placement of molar bands and tubes can be controlled relatively well and if the position is not as desired it may be corrected by re-cementation. However bonding other attachments on the teeth does provide considerable advantages. The process is painless and quick. There is no thickness of band material between adjacent teeth and this may be particularly important in marginal crowding cases. Bonded appliances are more comfortable for the patient. A range of ceramic and plastic brackets also offers much improved appearance although these brackets suffer from inherent weaknesses. Some children seem incapable of avoiding breakages and replacement of bonded attachments with bands is warranted. Bands are still used in certain circumstances including heavily filled or crowned teeth, sites of frequent breakage such as the lower second bicuspid and where lingual attachments are required for elastics. Bonded lingual attachments are available and seem to suffer dislodgement infrequently.

Bonding brackets in the correct position can present quite a challenge in the young patient where access and moisture control are difficult and not infrequently the patient is unable to sit still for even moderate periods. Most bonding is conducted by the direct method where the correct vertical and horizontal alignment of the bracket is judged by the clinician as the bracket is seated onto the surface of the tooth. Experienced clinicians obtain a satisfactory result in most cases although incorrect placements in the bicuspid regions are relatively frequent. Light cured bonding materials have helped in this regard because unlike with the chemically activated resins, the clinician can deliberate for as long as required before finally curing the adhesive with light. Correction requires debonding and rebonding of a

new bracket. Unless this is done the aligned position of the tooth will be incorrect and compensating bends must be placed in the same place in every arch wire throughout treatment. This can be particularly inconvenient apart from being virtually impossible to achieve. This means that the tooth is moved to a slightly different position with every arch wire change. It is better to rebond as soon as the mistake is realised.

Indirect bonding has some advantages in achieving consistency of bracket positioning which is often difficult with direct bonding technics. Direct bonding calls for on-the-spot assessment in three dimensions and allowance for variable crown morphology. In the incisor region this is not as difficult as in the canine and bicuspid regions. The bicuspid and canine crown morphologies often make it difficult for the clinician to place the bracket exactly. Upper second bicuspid brackets in particular are difficult to position satisfactorily in many patients. The difficulties are compounded in those cases where there may be varying amounts of crown rotation requiring that the bracket be offset prior to derotation of the tooth. Another problem is often caused by the need to place a bracket at the gingival margin in slightly under-erupted teeth. The tension in the gingival soft tissues will displace the bracket as soon as it is released from the tweezers when using a direct bonding technic. Alternatively the clinician has to hold the bracket until the adhesive has set. Accurate bonding of molars will also present problems in many cases. Obviously not all cases present these problems and in the patient with good access and the ability to remain still for a prolonged period, direct bonding will still provide a satisfactory result. Bonding of molars in adult patients where headgear is unlikely to be used and the patient is careful of the appliance is usually very successful.

INTER-MAXILLARY ELASTICS

Much orthodontic treatment is directed at the correction of the antero-posterior arch relationships. In Class II cases the upper buccal segments must move distally or the lower buccal segments must move mesially. In Class III cases the upper buccal segments must move mesially or the lower buccal segments must move distally. One of the most common mechanisms for helping to achieve these reciprocal movements is inter-maxillary elastics – Class II elastics for Class II cases and Class III elastics for Class III cases. Forces in the range of 60-100 grams are commonly used. Elastics are supplied in a range of diameters and each diameter size is available in a range of weights – light, medium and heavy. The clinician is usually able to match a particular elastic to the force requirements of the individual patient. For example, extraction cases will usually need smaller elastic sizes because of the reduced arch length. The intermaxillary elastics are attached to traction loops bent into the arch wire between the canine and lateral incisor while posteriorly they are attached to hooks welded to the molar tubes. The forces generated by these elastics may be resolved into vertical and horizontal vectors. The vertical vector tends to elongate the molars and incisor segments to which the elastics are attached. By

maximising the horizontal distance between the attachment points the horizontal vector is maximised and the vertical vector is minimised (Fig. 10).

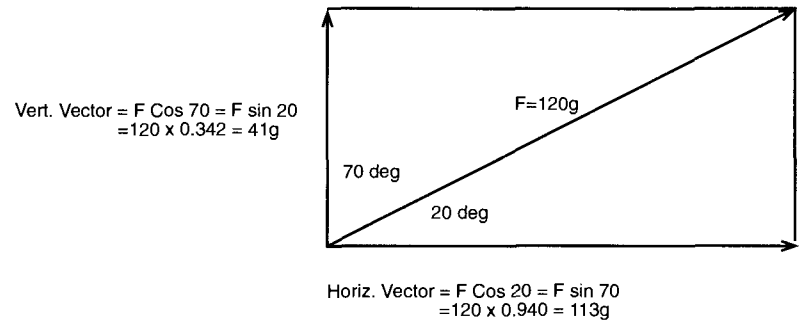


Fig. 10: Calculation of the horizontal and vertical force vectors from an elastic between the lower molar and the upper arch loop exerting a force of 120 grams.

The main determinant of the horizontal and vertical vectors is the force generated by the elastic. To reduce the extrusive vertical force, reduce the elastic force. In a Class II malocclusion with a deep bite we wish to reduce the overbite by intruding the upper and lower incisors at the same time as correcting the antero-posterior arch relationship. Intrusion of the incisors is achieved by placing anchor bends in the arch wire in the region of the second premolars. The amount of anchor bend is altered to provide about 80 grams of intrusive force on the incisors. This intrusive force in the upper incisor region is overcome to some extent by the vertical vector generated at the anterior attachment of the inter-maxillary elastics. At the same time the anchor bends will generate an extrusive force and distal tipping effect on the molars. The upper molars will tip distally while the lower molars will be prevented from tipping by the elastics. The extrusive effect on the molars may be largely balanced or overcome by the forces of occlusion if the vertical vector is not excessive. The forces generated by the arch wire and the elastics must be balanced to achieve the objectives without undesirable extrusion of teeth.

HEADGEAR

Headgear is frequently used as an adjunct to fixed appliance treatment. The headgear bow consists of inner and outer sections soldered together anteriorly. The inner section is adapted closely to the shape of the upper dental arch and fits into special tubes on the upper molar band. The inner bow incorporates a stop, often a U loop, in order to transmit the headgear force directly to the molar tooth. The U loop also provides an adjustment mechanism for lengthening or shortening the inner bow (Fig. 11).

There are many designs of headgear straps. Some utilise elasticised straps, others use coil springs while yet others employ elastic bands. In recent years, the danger posed by wearing headgear has become more widely publicised and eye injuries

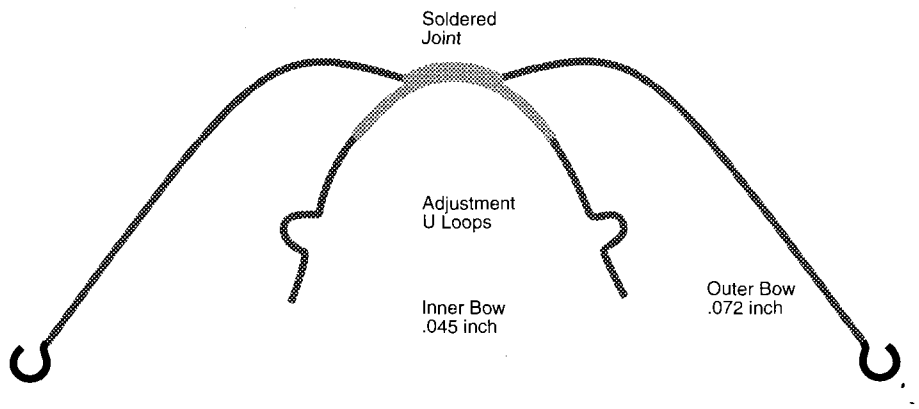


Fig. 11: Headgear face bow.

are of particular concern. For this reason various safety mechanisms have been incorporated including safety straps and snap-way traction devices which 'let go' when subjected to excessive force. Yet another safety design is the blind end inner bow. It is most important to explain these issues to the patient or parent as part of the informed consent process. Headgear strap design will also vary according to the desired direction of pull. There are three basic types - cervical or low pull, straight pull and high pull (Fig. 12). A simple strap around the patients neck will pull below the level of the molar tooth and will therefore extrude the tooth as well as moving it distally. In cases where it is desirable to avoid extrusion of the molar, the direction of pull must be altered. To provide intrusion as well as distalisation the direction of pull must be above the first molar.

Hours of wear will vary depending on the anchorage requirements of the particular patient. Where the upper teeth must be actively distalised, the appliance should be worn for at least 14 hours each day including while asleep. If the need is to reinforce anchorage rather than active movement, the hours might be reduced to bedtime only. Experience suggests that most children don't wear a headgear consistently for the required period each day. Many are erratic and unless the parents are supportive cooperation often falls away. When one sees the rapidity with which teeth move in the very cooperative wearer, one realises how few patients maintain high levels of compliance.

In Class III cases protraction of the upper arch is often required to overcome the retroposition of the upper teeth. For this purpose the Delaire face mask may be used with elastics attaching a frame against the forehead and chin to the upper arch. These are relatively comfortable to wear (Fig. 13). When used in conjunction with heavy orthopedic forces they may achieve some protraction of the maxillary bones by altering growth at the circum-maxillary sutures. With lighter forces they provide a very useful mechanism for moving the upper teeth forward when the use of Class III elastics may not be desirable or effective.

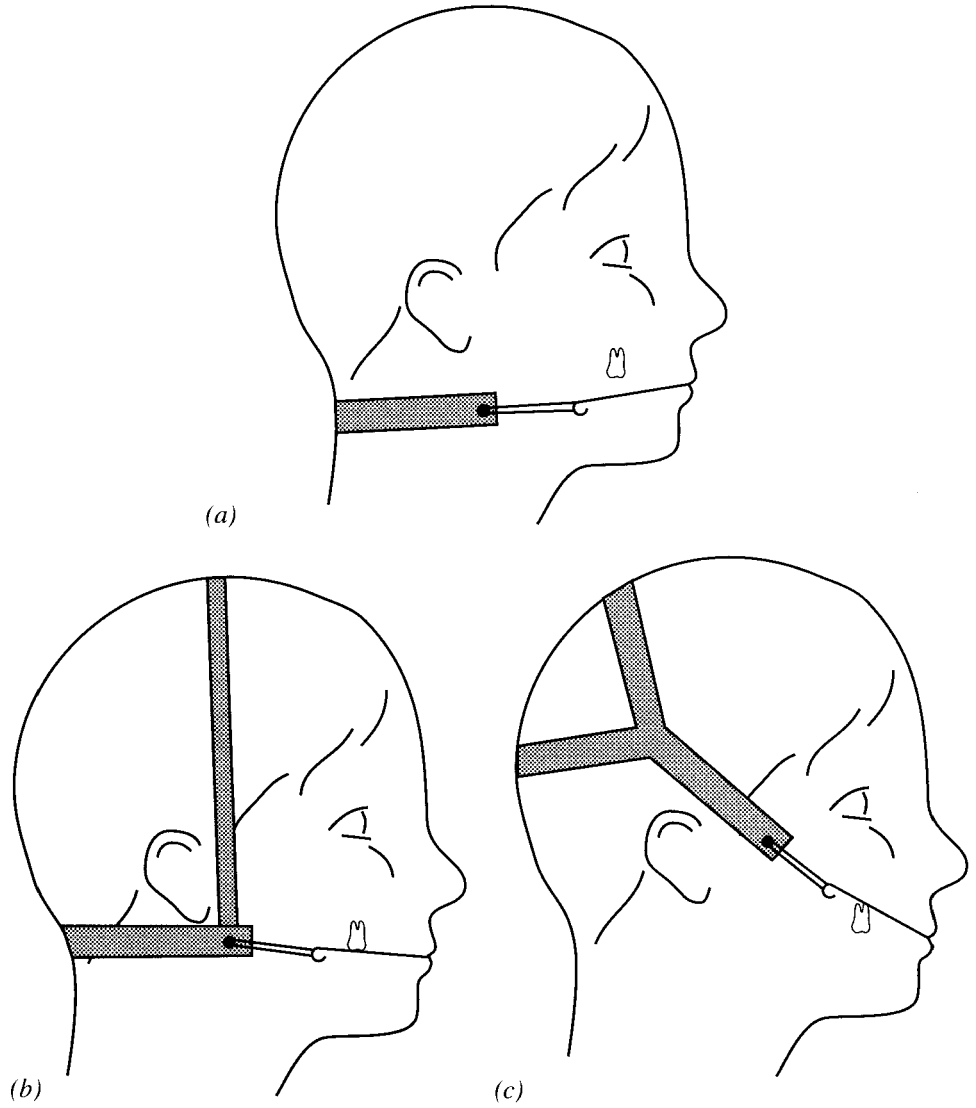


Fig. 12: (a) Cervical pull headgear tends to extrude molars (b) straight pull headgear to reduce extrusion effects (c) high pull headgear for active intrusion of molars.

FIXED APPLIANCE MANAGEMENT

The major choice of appliance is between the Begg system and the edgewise appliance (Fig. 14). The Begg appliance has waned in popularity in the last five years or so and has to some extent been displaced by the hybrid tip-edge system. The difference between Begg and edgewise is fundamental. The Begg system relies on tipping and subsequent torquing and uprighting. The edgewise system limits tipping and generally aims to move teeth by control of the centre of rotation at all stages of treatment. The tip-edge system purposely employs a mixture of tipping and axial control.

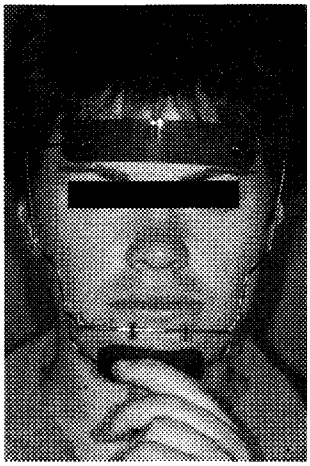
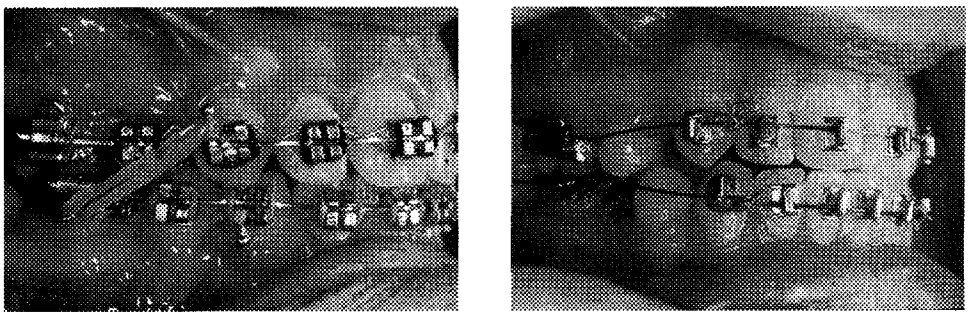


Fig. 13: Delaire face mask for reverse maxillary arch traction.



(a) *(b)*

Fig. 14: (a) Edgewise fixed appliance with Class II elastics (b) Begg fixed appliance.

Management in a practice employing fixed appliances on a day to day basis requires well defined office procedures which are designed to ensure that:

- patients and parents understand their responsibilities
- the length of each appointment is carefully scheduled for the particular operation
- the appliances are carefully examined for breakages or loose bands at every appointment
- oral hygiene is checked at each appointment
- emergency procedures are well understood by staff and patients
- missed appointments are followed up within a short time.

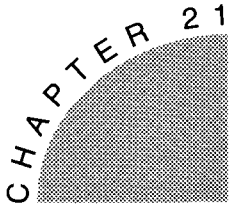
Research by Prove (1996) and Atkins (1996) strongly suggests that patients and parents often have a poor understanding about the detail of fixed appliance treatment even after explanation. People find it difficult to understand what they have not experienced. On first presenting, many patients and parents have little appreciation of the time, inconvenience and frequency of appointments associated with fixed appliance treatment. In those families where no other children have undergone treatment the realities of the commitment required are not appreciated even with

considerable explanation. This may help to explain the poor compliance seen in some children in spite of explanation prior to treatment. In short, the problems associated with prolonged fixed appliance treatment are often not understood until the treatment actually commences at which point the enthusiastic expectation of a quick and painless period of treatment is sometimes replaced by grudging compliance.

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ORTHOGNATHIC SURGERY

The underlying concepts of orthognathic surgery are now relatively old although procedures have been greatly refined in the last fifteen years. Skeletal abnormalities of the jaws may occasionally be marked and therefore beyond satisfactory correction by means of orthodontic treatment alone. In very general terms the limitations of orthodontic tooth movement are dictated by the initial angulation of the tooth relative to its final position, the type of appliance, the severity of the pattern and time. Even with fixed appliances, where teeth must be moved horizontally without tipping more than six or seven millimetres, orthodontic treatment is likely to be very prolonged and utterly reliant on good patient cooperation throughout the total period of mechano-therapy. Anchorage is likely to be lost and loss of torque control may result in undesirable tipping. Where incisor teeth are badly tipped forward prior to retraction, orthodontic treatment will usually provide an acceptable result even in a case with a very large overjet. Cephalometric analysis of the underlying structural relationships is the best way to determine the treatment options.

Another factor of significance is the age of the patient. In adult patients where growth has ceased it may be quicker, more convenient and more predictable to correct even less severe problems by means of surgery. The inconvenience of prolonged orthodontic treatment may be greatly reduced by a combination of orthodontic treatment and orthognathic surgery. The decision to undertake surgery must always be balanced by a consideration of the benefits against the disadvantages, particularly post-surgical morbidity. However, the reliability of anaesthetic and surgical methods has significantly reduced post-surgical problems. Surgery is seldom welcomed by any patient and this natural reluctance acts as an important filter in the informed consent process. Some patients will refuse surgery no matter what the perceived benefits.

While much orthognathic surgery is directed to the correction of antero-posterior skeletal anomalies, refinements have recognised the need for correction in the vertical dimension. Antero-posterior skeletal correction of the mandible may also require vertical adjustment of the maxillary dentition at the same time – either impaction or extrusion. In addition there is frequently a need for lateral correction of the arches. The objectives of surgery will be determined by those same factors previously examined in the analysis of malocclusions to be treated orthodontically. Class II malocclusions may be caused by a maxillary protrusion, mandibular retrusion or both. They may be associated with a high angle open bite pattern requiring maxillary posterior impaction to allow the mandible to rotate up sufficiently to eliminate the openbite as well as mandibular advancement. Class III malocclusions may be due

to maxillary retrusion, mandibular protrusion or both. Correction of these types will often require both maxillary advancement and mandibular set-back. Once again an openbite problem will require maxillary impaction.

Normal occlusion requires that the upper and lower dental arches are coordinated laterally. The upper arch widths must match the lower arch widths to ensure correct occlusion and buccal overlap. As the upper and lower skeletal arches become displaced relative to each other, coordination is lost simply because of the displacement. Coordination may be further disturbed by lateral skeletal anomalies such as maxillary contraction or mandibular expansion as commonly seen in Class III malocclusions. Thus much of the effort of pre-surgical orthodontic treatment is directed to achieving arch coordination after surgical correction. During this phase the dental arches may become temporarily uncoordinated until surgical movement re-establishes lateral coordination.

TIMING OF TREATMENT

Early surgery for craniofacial anomalies is mostly undertaken for extreme congenital defects such as cleft lip and palate, branchial arch defects or some of the more unusual morphological syndromes. Orthognathic surgery is not normally recommended for the treatment of malocclusion until the patient has reached the stage of skeletal maturity. Skeletal growth prediction is not an accurate process and it is not justified to undertake orthognathic surgical correction of a malocclusion in the growing child based on predictions of future growth. It is more desirable to undertake remedial interceptive orthodontic treatment. However, the clinician is frequently presented with the dilemma of balancing the marginal improvements of prolonged interceptive orthodontic treatment against the decision to wait until nearer the completion of growth for orthognathic correction. This delay may present real problems of psychological development for some children and there is no easy answer. Occasionally for example, in Class III malocclusions, the clinician will be justified in extracting teeth in a very crowded maxillary arch to obtain an improvement in alignment without any improvement of the arch relationships. This will at least give the patient a better appearance during early adolescence. In spite of the best intentions, most patients will tire of lengthy orthodontic treatment procedures and the clinician is in the unenviable situation of trying to maintain the interest of the patient when treatment must be staged over the period of skeletal and dental development.

MANDIBULAR CORRECTION

Antero-posterior correction of the position of the mandible necessitates splitting the mandible on both sides creating an anterior tooth bearing fragment and two posterior condyle bearing fragments. Body osteotomies involve splitting the tooth bearing portion of the mandible and are now used relatively infrequently. Very

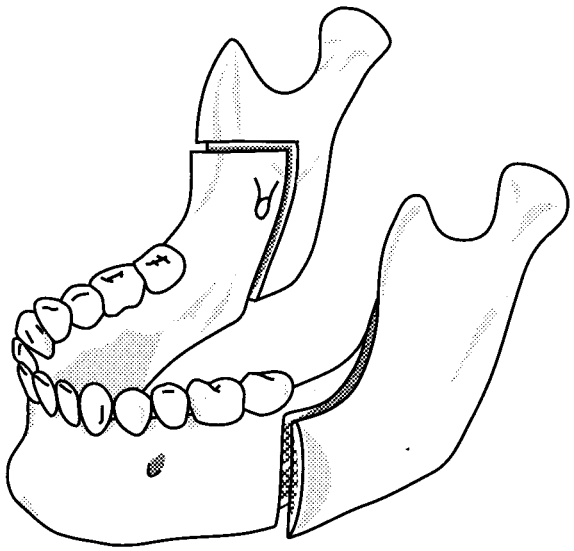


Fig. 1: Bilateral saggital split osteotomy dividing the ramus of the mandible and forming one tooth bearing fragment and two condyle fragments.

commonly these days the technic of bilateral sagittal split osteotomy is used to alter the position of the mandible. The sagittal splits are made through the rami in such a way that after the shift is complete, there is apposition of the cut medullary surfaces in order to ensure rapid healing. The analogy of a telescope helps to visualise the overlap of the two fragments such that sufficient area of bone is apposed for healing (Fig. 1). The sagittal split may be used to move the anterior fragment back but other technics may be better adapted. Operation on the ramus as opposed to the body of the mandible leaves the tooth bearing portion intact. After completion of the operation the position of the body of the mandible must be correct and the condyles must lie in their normal positions in the fossae. Correction of the body of the mandible with displacement of the condyles out of the fossae is clearly not going to be stable and will cause joint dysfunction.

Correction of vertical problems such as reduced facial height by lengthening of the ramus is usually not recommended. Lengthening of the ramus will stretch the mandibular sling muscles leading to relapse. Detachment of the insertions may be justified to help overcome this problem. Where the anterior face height must be increased to relieve a deep bite, it is more desirable to perform a ramus split which allows the chin to move down and forward by rotation of the body of the mandible in the surgical site rather than at the condyle and thereby avoiding ramus lengthening.

Post-surgical morbidity may include paraesthesia although this is generally short term and usually disappears within 6 months. Frank permanent anaesthesia may result infrequently where nerve damage is permanent. Pre-surgical counselling and the informed consent process must address these issues squarely with the patient and it is highly desirable to request the patient to complete a written informed consent prior to surgery.

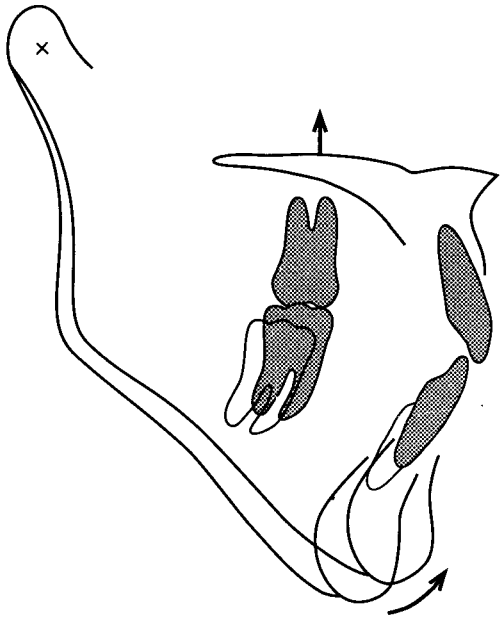


Fig. 2: Impaction of the maxilla allows the mandible to rotate at the condyles so that the symphysis moves upwards and forwards. The new position of the upper arch must accommodate the new position of the lower arch.

MAXILLARY CORRECTION

Class II malocclusion is frequently associated with relative maxillary protrusion while Class III malocclusion may be associated with maxillary retrusion and /or mandibular protrusion. Correction of the antero-posterior position of the mandible in Class II cases often requires rotational adjustment of the body of the mandible, particularly where there is a vertical facial excess and openbite. The ultimate vertical position of the mandible will be determined by the vertical position of the maxillary arch and impaction of the maxilla is required in addition to the upward and forward rotation of the mandible at the condyle (Fig. 2).

The maxillary position is corrected by means of a LeFort osteotomy. With down fracture, the maxilla is detached from the superior buttresses and nasal structures. Depending on the amount of maxillary impaction required, bone is removed in the superior aspect of the maxilla and the paranasal regions to permit the impaction (Fig. 3). The maxilla is also detached from the medial and lateral pterygoid plates. After complete mobilisation the bone is repositioned. Depending on the requirements of the particular case, differential impaction may be required anteriorly or posteriorly. A similar procedure without the removal of bone may be used to detach the maxilla and extrude it. Occasionally, in cases showing severe asymmetry, such as condylar hyperplasia, impaction may be required on one side and extrusion on the other side.

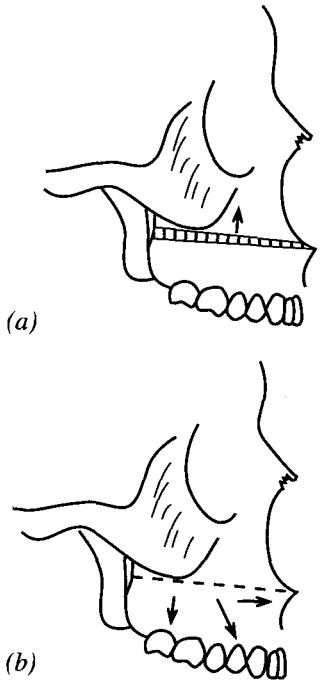


Fig. 3: (a) LeFort down fracture of the maxilla with bone removal and subsequent impaction (b) down fracture for elongation and forward shift of the maxilla.

ANCILLARY PROCEDURES

While shifts of the maxilla or mandible will be required to correct substantial skeletal anomalies, supplemental procedures are often required to improve facial appearance or to correct local anomalies. Often the LeFort I down fracture is done as a one-piece procedure and in this instance there is no opportunity to alter the width of the upper arch. Some surgeons are willing to split the maxilla palatally thereby providing opportunities for the correction of a crossbite or asymmetry at the time of operation. Alternatively a two stage augmentation procedure may be carried out . In adults rapid orthodontic expansion with a palatal expansion screw may be hampered by sutural fusion. The process can be augmented by palatal and lateral maxillary corticotomies prior to the rapid expansion. The corticotomies reduce the bony resistance to rapid expansion. In the younger patient surgical augmentation is not usually required. The second stage surgical procedures are performed at a later date after lateral arch coordination has been attained and presurgical orthodontics completed.

The chin region frequently requires additional attention. A forward shift of the mandible in patients with an already strong symphysis may provide correction of the arch relationships but leave the patient with an excessively protrusive chin. In yet other patients the receding nature of the chin may require augmentation even after a forward shift of the mandible. Both these situations may be improved by a

pedicled sliding genioplasty where the symphysis is cut from the body of the mandible and slid forwards or backwards to augment or reduce the chin (Fig. 4). Lateral movement of the symphysial segment may help to correct an asymmetry. Augmentation of the chin may also be achieved by means of a graft, either an allelograft or an autograft. Allelografts of various materials including nylon, teflon and tantalum have proven to be generally disappointing in the relatively superficial position of the chin with the thin tissue covering. Autografts of bone may be more successful initially but will eventually suffer from resorption.

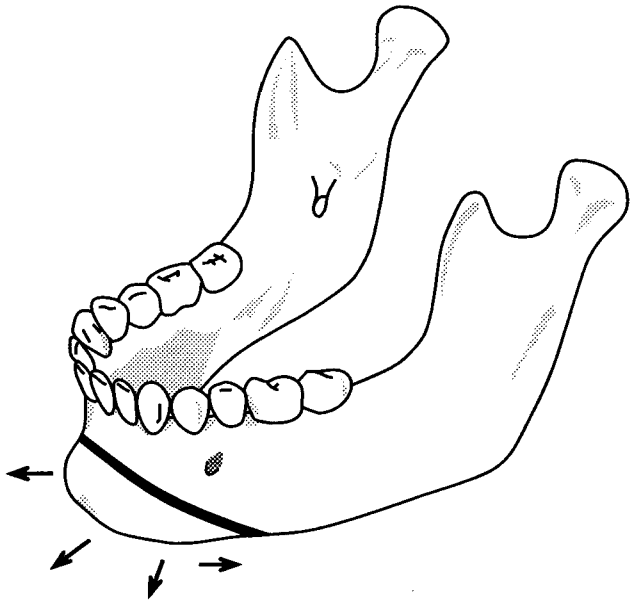


Fig. 4: Sliding genioplasty which allows adjustment of the symphysis in an anterior, posterior or lateral direction.

Occasionally localised alveolar movements are required to overcome deformities. For example very early loss of permanent posterior teeth in one arch may lead to extensive over-development of the teeth and alveolus in the opposing arch. Rapid and effective correction of the anomaly may be achieved by an alveolar osteotomy with localised division of the alveolus in the region followed by impaction.

In some cases of increased overjet where the upper first premolars are to be extracted, it may desirable to correct the overjet by means of a segmental osteotomy of the maxilla anterior to the extraction sites. After mobilisation of the anterior fragment, sufficient bone is removed in the extraction sites to allow the fragment to be moved back to the correct relationship with the lower teeth. Experience suggests that great care must be taken to ensure that the fragment does not undergo rotational relapse with the upper incisors becoming proclined again (Fig. 5).

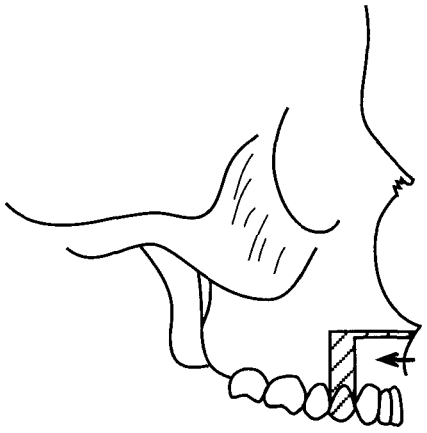


Fig. 5: Segmental maxillary osteotomy with extraction of the first bicuspids and posterior shift of the anterior tooth bearing fragment.

SURGICAL IMMOBILISATION

Immobilisation of the bony segments is required to achieve healing in the corrected position and to prevent surgical relapse. Previously immobilisation was achieved by means of osseous wiring to connect the fragments. In addition the jaws were often wired closed to ensure that there was little movement between the fragments. The more recent development of rigid fixation technics using bone screws and plates allows the immediate movement of the jaws relative to each other and there is little need to wire the jaws together. The patient can resume function, along with physiotherapy, within a period of days. The plates and screws are left in place. When the patient is able to function satisfactorily, the finishing stages of orthodontic treatment can be commenced. This usually consists of vertical elastics to seat the teeth in the buccal occlusion. During this phase the heavy stabilising archwires placed prior to surgery are replaced by relatively light flexible wires or sectional arches to allow differential settling. Depending on the original malocclusion, Class II or Class III elastics may be required to augment the surgical correction.

POST-SURGICAL RELAPSE

Post-surgical relapse is a matter of significance in treatment planning and in the informed consent process. Large surgical corrections are more likely to be followed by some relapse. Open bite corrections seem most likely to suffer some relapse toward the original condition. However as experience has accumulated and modern fixation technics have been refined, relapse has been minised to predictably acceptable levels in the majority of patients. Most significant relapse problems are associated with larger bone movements or where the post-surgical positions of the bone fragments are in conflict with the functional muscular environment such as is likely to occur with elongation of the ramus length.

ASSESSMENT OF THE PATIENT

Orthognathic surgery is usually performed on the attainment of skeletal maturity to minimise the possibility of relapse associated with continued growth. Sensible planning will dictate the commencement of orthodontic treatment so that this stage is completed to coordinate with the surgery in the young adult stage. However severe skeletal dysplasia such as first branchial arch deformity may require a series of corrections from an early age. Another important consideration is the psychological maturity of the patient. In spite of the tendency of many clinicians to underestimate the impact of these procedures on the patient and parents, it is clearly very wise to ensure that the patient is able to fully grasp the significance of the proposal as well as the inconvenience and discomfort which will be encountered. An attempt must be made to prepare the patient and parents for the facial changes which will occur. This can be done by means of a computerised treatment graphic in which the positions of the bones and overlying soft tissues after treatment are interpolated.

Opportunities for discussion and explanation will relieve many of the patient's fears. In some cases however the patient's expectations will obviously be unreasonable and particular care must be taken, even to the point of seeking a professional psychological assessment. The unhappy post-surgical patient is very difficult to satisfy and apart from any legal consequences the objectives of treatment are totally lost if the patient is not relatively happy with the outcome. Post-surgical relapse is as much a fact of life as post-orthodontic relapse and should be explained to the patient. In particular, care should be taken in those patients displaying symptoms of temporomandibular dysfunction. Orthognathic surgery cannot guarantee alleviation of the symptoms of dysfunction. Careful pre-surgical explanation will obviate many problems of patient dissatisfaction.

Van Steenbergen and Nanda (1996) reported on patient satisfaction relative to orthognathic surgery and found that orthodontists' ratings of facial views were neither predictive of the patient's satisfaction with appearance or self-concept. They were moved to comment that orthodontists "may be well advised to to review even more carefully with patients the procedures they are planning" and that the orthodontist's assessment "is of less importance to a patient's satisfaction than his or her feelings about their own self worth". These comments highlight the considerable significance of evaluating and discussing the patient's desire for treatment and ultimate satisfaction with the outcomes of treatment. It should never be assumed that patients and parents will necessarily view changes in facial appearance as a result of surgery as being desirable, no matter what the clinician may feel or advise. The opinions of friends and relations are sometimes critical to achieving satisfaction with altered facial appearance.

COMPENSATION AND DECOMPENSATION

As a malocclusion develops, there will often be a natural compensation by the tissues and functional patterns to overcome the anomaly. In Class III malocclusions

the lower incisors may become retroclined and the upper incisors may become proclined. In Class II malocclusions the lower incisors may become proclined. Such compensation will tend to mask the underlying skeletal abnormality. In these cases the orthodontic treatment will include decompensation to permit sufficient surgical change in the jaw positions to correct the underlying skeletal relationship.

In the severely prognathic occlusion if the lower incisors are already retroclined, as the mandible is positioned posteriorly and the maxilla anteriorly, the incisor relationship will become distinctly abnormal with an increased overjet and poor inter-incisor relationship. Pre-surgical orthodontic treatment is often undertaken to procline the lower incisors and to retrocline the upper incisors, perhaps with extractions in the upper arch. This will cause a substantially worse reverse overjet in this stage of decompensation. However after the surgical correction, the incisor relationship will now be normal with an acceptable inter-incisal angulation (Fig. 6).

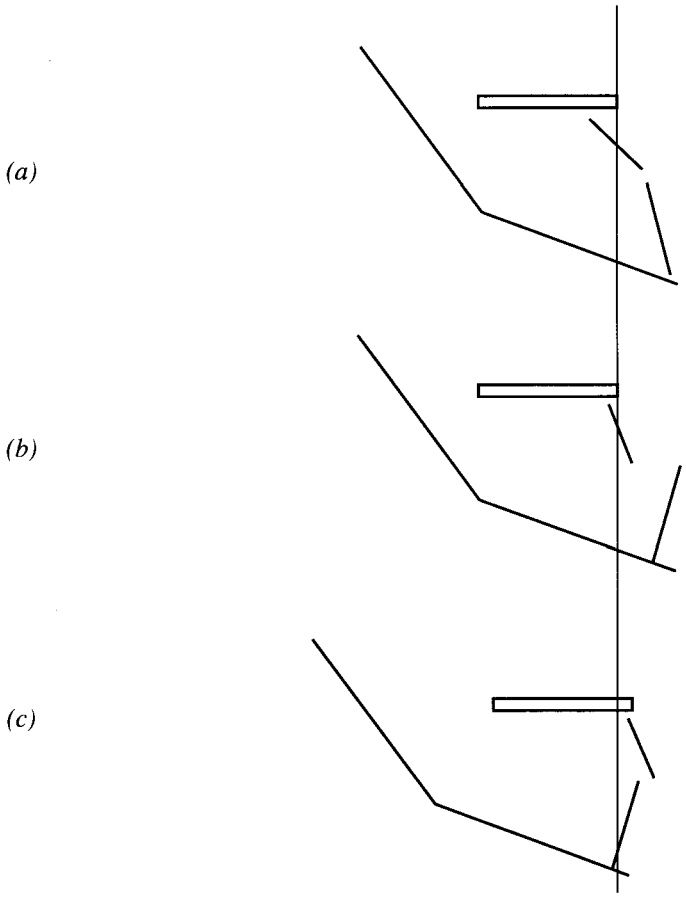


Fig. 6: Stages in decompensation of a Class III malocclusion (a) original malocclusion with teeth in compensating positions (b) decompensated positions prior to surgery (c) surgical correction of the jaw bases and the teeth in the decompensated positions.

Similarly, decompensation in the patient with a retrognathic occlusion will be designed to retract the lower incisors, often with lower extractions, causing an increase in the overjet and temporary deterioration in the patient's appearance. At surgery the mandible will be advanced to correct the skeletal relationship. One of the main aims of orthodontic decompensation is to provide sufficient horizontal distance between the incisors to allow adequate surgical shift to produce a pleasant profile and a stable inter-incisal relationship.

TREATMENT SEQUENCING

Primary responsibility for management of the orthognathic patient will usually be undertaken by the orthodontist or the oral surgeon. Treatment planning is largely determined by consultation between them. Depending on the type of problem other consultants will be called upon from time to time including the prosthodontist, plastic surgeon, ear nose and throat physician, speech and hearing pathologist and psychologist. Cleft palate patients are more likely to require ENT attention. Other specialist dental advice will occasionally be required. After the initial appointment, detailed case analysis begins with the collection of a full set of case records. Final formulation of the treatment plan will be done after multidisciplinary specialist review and consultations with the patient and spouse or close family. Modern computer graphic simulation systems may be of help in giving the patient some idea of the changes to be expected. Finally the patient should be requested to formally accept the treatment plan, preferably by signing an informed consent form.

Orthodontic treatment is commenced and in most cases can be expected to take about 18 months particularly where teeth have been extracted as a part of treatment. Joint consultative reviews should be conducted with the oral surgeon as the orthodontic treatment progresses, particularly in the last few months when surgery and hospitalisation arrangements must be made. At this time the orthodontist will usually take impressions for working models which can be used in a joint planning meeting. Models will also be required immediately prior to surgery for the construction of bite locating wafers. When the surgeon is satisfied that surgical objectives can be met, the operation is performed. The immediate post-surgical period is devoted to evaluation of the fixation procedures to ensure that healing is uneventful. In suitable cases a program of gentle exercise and perhaps physiotherapy will be instituted to help the patient to regain full function.

When the patient is comfortable, a set of post-surgical records will be obtained as a record of the correction and for comparison with pre-treatment records. In many cases further orthodontic treatment may be required to settle the occlusion, to correct minor occlusal problems and to ensure that retention is adequate. A further joint review with the oral surgeon is recommended at this time as well as other specialists. In cases exhibiting any disquiet with the result a further psychological evaluation may be required. Within eight to twelve weeks the appliances may be removed and orthodox retainers placed. Thereafter the orthodontist will usually manage the

occlusal retention phase with reviews of the surgical result by the surgeon as required until stability is achieved. Cases exhibiting relapse tendencies may present intense management difficulties and on some occasions further surgery may be required.

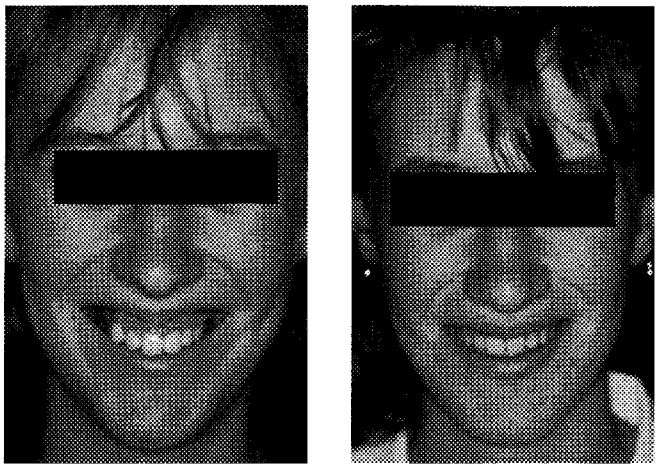
Care and consideration for the patient's total wellbeing is required throughout the whole process. Questions and concerns must be addressed honestly. In the immediate pre-surgical and post-surgical phases, the clinician might consider a personal phone call if difficulties are suspected. It is easier to short-circuit problems than to allow them to develop and then try to recover the situation. Every effort must be made to ensure the patient is as comfortable as can be expected.

CASE REPORT

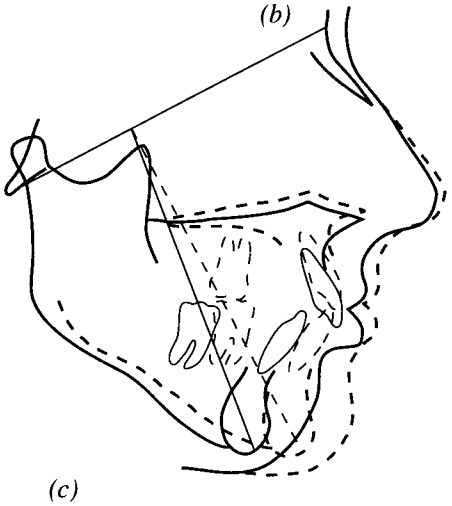
The patient presented for orthodontic treatment, aged 15 years 9 months, the chief concerns being protruding upper teeth, crowding and a 'gummy' smile. The medical history was normal. Oral hygiene was fair. The upper left permanent canine had been extracted two years previously because of crowding. The patient had a good supportive family background and was well adjusted emotionally. After explanation she was keen to pursue treatment. The facial profile was extremely convex with considerable lip strain on closure. The anterior face height was increased. There was excessive gingival exposure on smiling. The temporo-mandibular assessment revealed a full range of movement without tenderness or deviation on opening. There was no history of bruxing. There was mild clicking in both joints on opening (Fig.7).

Dental analysis revealed the upper midline was displaced 3mm to the left side. The molar relationships were a full unit Class II. Both arches were constricted and crowded. The cephalometric analysis showed the skeletal pattern to be dolichofacial with a high mandibular plane angle, ANB angle of 8 degrees and a Wits value of 11mm. The mandible was severely retrognathic and the maxilla was slightly retrognathic. The anterior face height was increased.

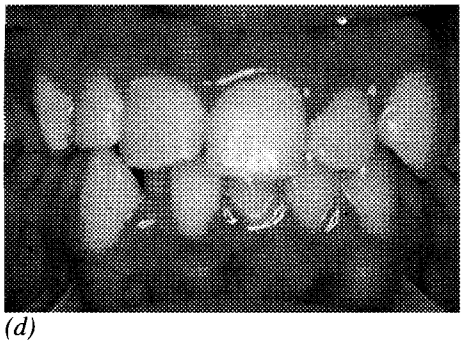
In view of the loss of the 23, it was proposed to extract the 14, 34, 44 and the third molars prior to arch alignment and minor decompensation. Orthodontic treatment took sixteen months. The surgery included maxillary impaction and advancement and mandibular advancement and rotation in association with a bilateral saggital split osteotomy. The post-surgical result shows a marked improvement in the profile convexity and the masking of the original smile problem. The superimposed tracings show that there was impaction and protraction of the maxilla as well as protraction and rotation of the mandible. The final occlusion was normal.



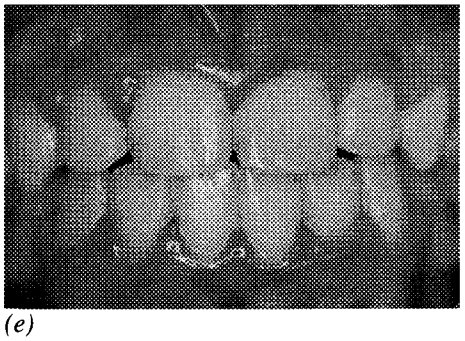
(a) (b)



(c)



(d)

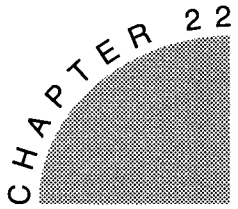


(e)

Fig. 7: (a,d) Pre-treatment face and occlusion (b,e) post-treatment face and occlusion (c) pre-treatment tracing (solid line) and post-treatement tracing (dashed line) demonstrating the maxillary impaction and mandibular rotation.

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Van Steenbergen E and Nanda R (1966): Presurgical satisfaction with facial appearance in orthognathic surgery patients. Amer J Orthodont Dentofac Orthop 110:653-9.



PATIENT EXAMINATION

Examination of the patient for orthodontic purposes is in several respects different from the routine examination of a dental patient. Some textbooks elaborate an extensive list of items for assessment, the implication being that each item will be analysed every time a new patient is seen. This is not the case. Neither does it reflect the usual method of initial examination carried out by orthodontists. Identification of a malocclusion is based on the simple assessment of relatively few salient items including overjet, overbite, crossbite, openbite, crowding or spacing, buccal segment relationships and facial appearance. If the patient passes the test on each of these there is probably little need for orthodontic treatment, apart from management of other anomalies as discovered on x-ray.

Once a decision has been made that there may be a need to treat one or more features, then a more formal orthodontic examination is undertaken. At this point the general dental practitioner will often refer the patient to a specialist colleague for management. If however the general practitioner wishes to undertake the treatment, then a standard methodology with suitable records should be implemented. Often the practitioner will delay referral or treatment, in which case only a minimal set of records might be obtained to provide a baseline for future review.

The usual process of orthodontic assessment requires at least two or preferably three appointments. The first appointment involves the initial examination. Often x-rays and other diagnostic information will not be available. If a decision is made to do further investigation, the patient is sent for x-rays which are made available for the patient's second appointment. At the second appointment, impressions for study models are taken and a brief examination of the x-rays is made. In addition the clinician makes further detailed notes of the patient's condition. Between the second and third appointments, the clinician undertakes a detailed analysis of all the records including a cephalometric analysis if indicated. The x-rays are examined carefully for anatomical and pathological anomalies. The study models will provide further information on crowding, spacing and occlusion. At this stage the clinician is able to formulate a tentative treatment plan. Finally at the third appointment, the records, conclusions and treatment plan are presented to the patient and parent for discussion and agreement (Fig.1). Active treatment usually commences at the fourth appointment.

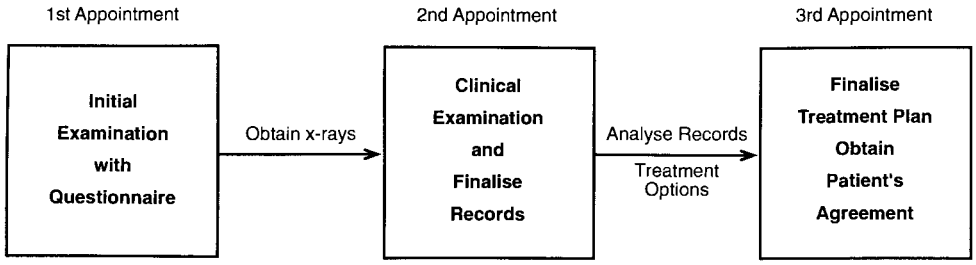


Fig. 1: Schedule of appointments for orthodontic diagnosis and treatment planning.

INITIAL EXAMINATION

The initial orthodontic examination will rarely finalise the treatment plan. The patient and the parent attend because they have been advised to do so or they have identified a problem for which advice is required. The examination should concentrate on the reason for attendance with notes for later recall by the clinician. It is highly desirable to obtain some background information from the patient or parent before the examination begins. This can be done by means of a short questionnaire.

Is the patient or parent genuinely concerned or have they been sensitised to a feature by the dentist or someone else? Often the patient or parent will express considerable relief when advised that there is little need for treatment. Because so much orthodontic treatment is carried out on children, it should not always be assumed that the parent and patient are in agreement about the reason for attendance or the need for treatment. The experienced clinician will have encountered the difficult situation of conflict between the parent and the adolescent teenager in particular. This is not simply a matter of youthful reluctance as might be seen with some young patients who do not understand the issues. Often the adolescent patient will have a fundamental disagreement with the parent concerning need for treatment and the clinician must be careful to seek the opinion of the patient as well as the parent. No orthodontic treatment can succeed without reasonable patient cooperation. The initial appointment should therefore concentrate on identifying those issues which are of special interest to the patient and parent.

A standard pro-forma questionnaire can be particularly helpful in eliciting useful information. The parent or patient is asked to fill out the short questionnaire before entering the surgery at the first appointment. Who is the referring dentist? Has the patient seen another dentist/orthodontist for the present problem? Has the patient had previous orthodontic treatment? Has anyone else in the family had orthodontic treatment? What is the problem for which help is sought? Does the patient suck the thumb or fingers? Is there an airway problem? (Fig. 2). Answers to these questions will always give the clinician valuable insights to the parent's and patient's perceptions of the need and demand for treatment. Previous treatment or consultations might alert the clinician to a need to be circumspect in offering advice

New Patient Questionnaire

Lastname _____ **Firstname** _____ **Sex M/F** _____

Date of Birth _____ **Date of Exam** _____

Did you bring a letter of referral (Y/N)? ____ **Referred by** _____

Has the patient had previous treatment (Y/N)? ____ **When?** _____

If so, what was the treatment? _____

Has the patient seen an orthodontist (provide name)? _____

_____

Reason for attendance? _____

Have any other family member had orthodontic treatment for a similar problem?

_____

Does the patient have a finger or thumb sucking habit (Y/N)? ____

Have the tonsils or adenoids been removed (Y/N)? ____

Does the patient grind the teeth (including when asleep)? ____

Other information _____

_____

(It is assumed a separate medical and dental history will be obtained)

Fig. 2: Short questionnaire to be filled out by the parent or patient before the first appointment.

and certainly no criticism of other practitioners should ever be offered even if it is sought. A family history of similar malocclusions can help the parent or patient to understand the difficulties which might be faced in treatment.

Examination of the patient is made after the above formalities have been completed. The initial examination should be simple. What are the main occlusal anomalies? Do these affect the patients appearance? Does the patient's age suggest that treatment may be better postponed? Is the patient able to wear the types of appliance which might be contemplated? Is treatment necessary to improve oral health or appearance? Are there other factors such as overseas travel or school formals which will significantly influence the conduct of treatment? Is there evidence of excessive sugar intake? How often does the patient visit the dentist? Are there clinical signs of periodontal disease? Are there signs of temporo-mandibular dysfunction?

DETAILED EXAMINATION

The record form should be suited to the purpose (Fig. 3). The form should not be too detailed with a long list of items that are rarely scored. Examination should include the following items:

(a) Medical and dental history

(b) Oral health examination

(c) Assessment of soft tissues

(d) Assessment of skeletal relationships

(e) Assessment of dental anomalies

(f) Brief functional analysis

History

The examination should begin with a medical and dental history filled out by the parent where the patient is a minor. Apart from the more obvious implications of medical problems which may be associated with cardiac anomalies or a history of transfusion for example, occasionally the clinician will come across conditions which affect dental development. A family dental history of missing teeth is always of interest. In addition, the clinician should carefully screen for a history of trauma. Occasionally a patient will present with a history of skeletal trauma and perhaps condyle fracture. Traumatised teeth are always likely to show discoloration and reduced vitality which may show up during tooth movement. The parent should be warned of such a possibility. In many cases these teeth will require root treatment. Where a tooth has been avulsed, its longterm prognosis is doubtful due to external root resorption which makes the extraction of other teeth a difficult decision. However, trauma may not always be reported. Children suffering 'minor' dental trauma at school may prefer to not report the incident to either the teacher or parent. Thus the parent's awareness of previous trauma may not be reliable.

The history should also seek information about the symptoms of temporomandibular dysfunction such as clicking, locking or pain and the presence of bruxing or grinding of the teeth at night. Most parents will volunteer this information if the child audibly grinds the teeth at night. The history sheet should seek information about habits such as thumb or finger sucking and when the habit ceased or if continuing how persistent the habit might be. Also request information about the frequency of oral hygiene and whether the patient consumes foods containing sugar on a regular basis.

Records

Records are an important part of the assessment process and should include:

(a) study models trimmed to centric occlusion by means of a bite record

(b) full mouth radiographs – usually an OPG plus occlusal x-rays

(c) a lateral skull cephalogram in case of a skeletal discrepancy

(d) photographs.

Impressions for models require properly selected trays and the correct amount of impression material to achieve well extended impressions without excess material

Last name _____ First name: _____ Dob: _____

Referred by: _____ Dental Care: regular irregular

Awareness of Malocclusion: – ├──────┤ +
Desire for Orthodontics – ├──────┤ +

History and notes

SOFT TISSUE ASSESSMENT

Lips: competent incompetent Airway: nose mouth both

Sucking Habit: finger thumb tongue How long? _____

Speech: normal lisp impediment Swallow: normal teeth apart tongue thrust

Comments: _____

SKELETAL ASSESSMENT

Profile Outline: normal retrognathic prognathic Lip Contour: normal full deficient

Vertical: normal low angle high angle Lateral: normal narrow wide

Comments: _____

DENTAL ASSESSMENT

Oral Hygiene: good poor Periodontal Status: good fair poor

Decalfication sites: _____ Caries: _____

Angle's Class: I II(1) II(2) III O'jet: O'bite: Trauma:

Comments: (rotation, crowding, frenum, missing, proclined, retroclined, openbite, centre lines etc.)

FUNCTIONAL ASSESSMENT

CO-CR Shift: nil left right ant-post Maximum opening: _____

TMJ: Right: normal click pain Left: normal click pain

Comments: _____

RADIOGRAPHY (caries, missing, ectopic, pathology, etc.)

Third Molars Present: Stage of Formation: early crown half complete

SUMMARY _____

TREATMENT _____

Fig. 3: Orthodontic examination record.

running down the patient's throat. Some patients become quite distressed by impressions particularly if they are prone to gagging. Experience suggests that belabouring the process with unduly extended or elaborate explanations usually makes the child more nervous. It is helpful to provide a pre-recorded explanation on audio or video tape and allow the patient to listen to this before commencing. A sympathetic and experienced dental assistant will usually be the best person to comfort the patient. Once the impression is placed in the child's mouth, the problems are often overcome by asking the child to hold the impression in place while leaning forward over a "dribble" bowl. This gives the child some measure of control of the situation and avoids panic.

Study models should be trimmed to a set plan with the height of each model being consistent so that a standard model box storage system can be implemented. The models should be poured in white stone and particular care taken not to fracture teeth during trimming. A wax squash bite is required to ensure the correct centric occlusion and to provide protection of the teeth when trimming one model against the other in occlusion. In patients with mandibular displacement to centric occlusion, some would argue that models should be trimmed in centric relation. This is extremely inconvenient and places the models in an abnormal vertical relationship due to cuspal interference. It is far more convenient to record the true centric relation photographically and compare the photographic record with the models trimmed to centric occlusion.

Soft Tissue Assessment

The clinician examines the morphology and function of the soft tissues to determine if they are implicated in the etiology of the malocclusion and whether they are amenable to improvement. In addition, the clinician must assess the balance of the soft tissues and whether treatment with extractions might adversely effect the patient's appearance. Do the lips meet at rest? Are the lips normal, flat or excessively protuberant? Is the lip line and exposure of the dento-alveolar structures acceptable? Do the lip positions directly reflect a retroclination or proclination of the teeth? Is there a functional muscular pattern which may be implicated in the aetiology of the malocclusion? Is there a speech anomaly which may also reflect a muscular functional anomaly? Mostly the answers to these questions are a matter of sensible observation and questioning while speaking to the patient and the parent. Unfortunately, we are unable to measure soft tissue form and function in the way that we are able to measure skeletal structures on a cephalogram.

Skeletal Assessment

Skeletal examination does not initially require a cephalogram. Careful clinical examination of the profile will provide useful information on the relative prognathism or retrognathism of the maxilla and mandible. Is the mid-face region protrusive or retrusive? Is the mandible protrusive or retrusive? Is the profile straight, convex or

concave? Is the mandibular plane angle normal, high or low? Are the facial proportions within normal limits? Is the facial height normal, increased or decreased? Are the upper and lower incisors normal, proclined or retroclined? The observant clinician can gain a large amount of relevant information. In the presence of a significant skeletal discrepancy, a more detailed cephalometric analysis is recommended. However, where the patient's skeletal pattern is obviously within normal limits and the occlusal relationship is Class I, there may be no need for a cephalogram, and the usual radiographic examination by means of an OPG and upper and lower occlusal x-rays will be sufficient.

Dental Assessment

Oral health examination should include notation of excessive numbers of fillings, decalcification, dietary examination where high carbohydrate intake is suspected, trauma, periodontal condition and soft tissue trauma. The patient's oral health status will frequently determine the objectives of treatment. Where oral hygiene is not acceptable, a treatment plan requiring the extended application of fixed appliances is likely to fail. Occasionally periodontal bone loss in adults will require the modification of treatment. The evidence of excessive sugar intake with extensive decalcification around multiple teeth may be a useful warning sign that serious pre-treatment education and counselling of both the patient and parent is required

The dental assessment will include examination of the casts as well as an intra-oral examination. Dental arch relationships and specific abnormalities are noted, varying from minor rotations of individual teeth to crossbite of a complete segment. In the mixed dentition, a space analysis may be required. Tooth sizes are important and notation of abnormally small or large teeth should be made. For example, small upper lateral incisors may require building up to the correct size. Tooth sizes may be analysed with the help of the Bolton analysis.

Functional Assessment

The dental examination is tied in with the assessment of temporomandibular joint function to uncover any relationships, contacts or conditions which may be causing or exacerbating a dysfunction problem. A functional examination of centric relation, centric occlusion and lateral movements is required to show the presence of abnormal contacts and whether a displacement is present. The temporomandibular assessment should include a careful notation of the present condition as well as palpation of the joints and the cranio-cervical muscles. Infrequently a patient might give a history of an over-riding medical problem such as chronic rheumatoid arthritis. The decision to seek further detailed joint radiography is based on the history, the type of condition and the age of the patient.

X-ray Examination

Full mouth radiographic examination is most conveniently achieved by means of an OPG x-ray, however, superimposition of the spinal column over the incisor region obscures the image. Upper and lower occlusal x-rays will overcome the deficiencies of the OPG in this region. It is tempting to not do a thorough radiographic examination. Experienced practitioners will attest to the number of problems which remain unsuspected until revealed on an x-ray. The OPG x-ray has proven to be an invaluable assessment tool and is easily obtained. Each child should have one OPG taken at about 10–12 years in the middle or late mixed dentition. Third molars are usually easily observed, aberrant tooth positions, particularly upper second premolars, can be intercepted and the general stage of development will give an indication of the urgency of orthodontic treatment where space management is required. For example, where a decision is made in principle to treat on a non-extraction basis, the urgency of treatment may be diminished if the the second deciduous molars are still present and not likely to exfoliate in the immediate future. Conversely, in the presence of some crowding and the need to preserve the leeway space provided by the deciduous molars, treatment in the lower arch in particular may become pressing.

Examination of the OPG should be systematic with the identification of each tooth and examination of the condyles which can be seen in most cases. Look at the x-ray for left-right asymmetries and inconsistencies in all structures. Suspicious findings should be followed up with more appropriate x-rays. Follow-up OPG x-rays in less than 18 months are rarely required. Tooth roots form at the rate of about 1.5 mm per year and taking x-rays does not make them grow any faster.

Consideration should be given to taking a lateral cephalogram where there is a skeletal problem or permanent teeth are to be extracted. Once again repeat cephalograms are rarely required within several years. One other problem of particular significance should be addressed and that is magnification. Each cephalometer produces a different rate of magnification. X-rays on different cephalometers may show large differences in magnification so that comparative measurements become unreliable. Where direct linear measurements are used in treatment planning these may be magnified by a substantial yet unknown amount. Where the x-rays are done by outside agencies such as radiologists, the clinician may have little idea of the rate of magnification. As in the examination process itself, the analysis of the cephalogram must be methodical and consistent.

Where the clinician takes a lateral cephalogram, this will ordinarily be traced and analysed in the interim between the second and third appointments. The filing of large x-rays may present a problem and each practice should give some thought to their efficient storage and easy retrieval. The observant and careful clinician will want to look at the OPG x-ray several times during treatment but not at every appointment. It usually better to file these large x-rays in a large separate envelope

rather than trying to design a patient card or folder to accommodate all x-rays. As the x-rays are examined, notations of important points are made on a reserved section of the patient's card. The emphasis of the examination will vary with the age of the patient. In young developing patients, the presence and developmental position of each unerupted tooth is examined, in particular the second bicuspid and the canines. In the adolescent patient, the presence and eruption status of third molars is examined more closely assuming that all other permanent teeth have erupted. In the adult patient the emphasis will shift to a periodontal perspective.

Treatment Plan

Some clinicians adopt a take-it-or-leave-it approach to treatment planning, often claiming that they are not prepared to let the patient dictate the terms of treatment. Such an approach is not realistic or even acceptable in terms of informed consent. The patient must always have the ultimate right to accept or reject the proposed treatment. While there are times when the clinician may be adamant that a particular treatment plan is clearly the best, in the majority of cases alternative strategies can be considered. This is particularly true of the need for headgear during treatment. Recent evidence shows that wearing a headgear carries an extremely small but identifiable risk of serious injury.

The specific objectives of the orthodontic treatment plan may be determined by factors unrelated to the malocclusion. The matters of need and demand for orthodontic treatment have not received much attention at the undergraduate level. Much orthodontic treatment is undertaken to improve esthetics with no improvement in oral health. Orthodontic treatment also carries the risk of actual damage such as root resorption. When the significant issue of post-treatment relapse is also considered, the clinician must be aware of the need to inform the patient of these issues in making a decision.

The treatment plan should be a carefully scheduled plan of action with a series of logical steps. It should note the need for other procedures later on such as a frenectomy or fibrectomy. It should also draw the clinicians attention to problem areas which require constant attention. Perhaps the best test of a treatment plan is whether another clinician can easily determine what is supposed to be happening, after a short examination of the patient's card. The clinician should also be cautious about written comments which may be misinterpreted by the patient who will undoubtedly read the entries on the card at some stage during treatment. Apart from avoiding the ire of patients or parents, it is medico-legally prudent to keep entries objective and uncritical as far as possible.

The treatment plan is a composite of objectives which are tailored to the individual patient. That might call for a trial period of treatment to be followed by further treatment determined by the response. For example, where the success of treatment depends totally on the patient's wearing a headgear cooperatively, the next stage of treatment will be contingent upon the success of the first stage. However, good

treatment planning must take account of conditions associated with each patient. Cooperation is a major factor in orthodontic treatment planning. Prolonged treatment over eighteen or twenty four months in the face of poor oral hygiene, is not sensible. Experience would suggest that cooperation is the single most important factor in the successful outcome of orthodontic treatment.

Informed consent requires that the parent/patient fully understand the proposed treatment and agree to it. Misunderstandings are generally overcome by providing the parent/patient with a written informed consent document. This does not need to be particularly long or complicated. A simple format (Fig. 4) has proven to be very effective. These forms are printed in self-copying blocks. When filled out and signed by the clinician and the parent/patient, the document is given to the parent/patient and the copy placed in the patient's record folder. An alternative method of providing informed consent is to send a copy of the letter to the referring dentist and to the patient as well. This is particularly effective if the detail in the letter is sufficient.

Consent Record

After examination of your records and discussions with you, orthodontic treatment is recommended and the elements of the proposed treatment are set out below.

Please note: _____

_____

_____

_____

Appliances (braces) on the upper/lower teeth . . . . . ☐

Length of active treatment with braces on the teeth (months) . . . . . ☐

Period of retention with a plate or fixed arch after treatment (months) . . . . . ☐

Extraction of primary (baby) teeth _____ ☐

Extraction of permanent (second) teeth _____ ☐

Wear of head gear (neck strap) as advised . . . . . ☐

Need for a denture after treatment . . . . . ☐

Oral surgery _____ ☐

Removal of wisdom teeth . . . . . ☐

Other details _____

_____

- It is highly recommended that you keep regular appointments with your own dentist during all orthodontic treatment. You should have regular checkups and fluoride application.
- A low sugar diet and careful tooth brushing are necessary to maintain oral health.
- Orthodontic breakages slow down your treatment. Please contact us immediately by phone in the event of problems.
- On occasions it is necessary to vary an orthodontic treatment plan where progress is not satisfactory. You will be advised if this the case and your approval will be sought.
- **If you do not understand any aspect of your proposed treatment, please seek further clarification and advice before you commence.**

CONSENT TO TREATMENT (Copy to parent/patient/dentist)

Patient's name _____

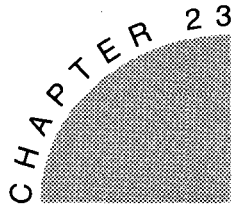
Consenting person (print) _____

Relation to patient (please tick) | parent | legal guardian | self |

Signature _____ Date ____/____/____

Orthodontist _____

Fig. 4: Informed consent record



CLINICAL MANAGEMENT OF PATIENTS WITH CLEFT LIP AND PALATE

INTRODUCTION

The multiplicity of problems associated with patients with cleft lip and/or palate (CLP) precludes treatment by just one speciality. A multidisciplinary team approach is essential to provide the best possible results in the overall management of patients with CLP. The key members of the cleft palate team include the plastic and reconstructive surgeon, the ENT surgeon, the speech pathologist and the orthodontist. In addition, there is support from other professionals: paediatrician, paedodontist, audiologist, oral and maxillofacial surgeon, social worker, psychologist and geneticist. There must be cohesion and effective interdisciplinary communication between all team members to ensure the co-ordination and staging of procedures to be performed by each speciality at the right time and stage of development. Some procedures involving two or more specialities are performed around the same time period. A co-ordinated approach is therefore required to ensure that surgical and non-surgical interventions by medical and dental specialities are provided during the same general anaesthetic session to minimise the overall number of general anaesthetics and painful episodes for the child with CLP.

An overview of the chronology of clinical procedures required for the successful management of patients with CLP is presented. It must be emphasised that there is no single, universally accepted protocol for the management of patients with CLP. Indeed, variations in the timing of repairs, bone grafts, surgical technique and orthodontic treatment exist within and between cleft palate teams throughout the world. This overview is based on the experiences of the cleft palate team at the Children's Oral Health Service.

THE CHILDREN'S ORAL HEALTH SERVICE

The Children's Oral Health Service (COHS) is located within the grounds of the Royal Children's Hospital (RCH) in the inner suburb of Herston, Brisbane. As a secondary and tertiary referral centre for the state of Queensland, this purpose-built facility officially opened its doors in October 1994.

Co-location of the orthodontic and paediatric dentistry units of the COHS within the RCH enhances the delivery of orthodontic care to children with cleft lip and/or palate, and for children with other craniofacial anomalies. It also assists in streamlining patient consultations and treatment through greater co-ordination within the cleft palate team at both the Royal Children's Hospital and Mater Children's

Hospital. These developments are particularly important for those children residing in country Queensland and northern New South Wales. Through the establishment of this facility, successive State and Federal governments have provided the opportunity for affected children to receive appropriate treatment at the appropriate time.

This chapter summarises the approach to the clinical management of children with cleft lip and/or palate within the framework of the Brisbane cleft palate team.

CLASSIFICATION OF OROFACIAL CLEFTING

It is important to understand that facial clefts are just one of a group of deformities of the craniofacial complex which are collectively called "Craniofacial Anomalies" (Whitaker et al, 1981). Table 1 provides an overview of craniofacial anomalies and demonstrates that clefting forms part of a much broader spectrum of facial deformity.

There are many methods of classifying clefts in the orofacial region. Tessier (1976) developed a comprehensive numerical classification system using the eyes and orbits as the reference points (Fig. 1). Clefts of the upper eyelid and above are called cranial clefts while those of the lower eyelid and below are called facial clefts.

Clefts	— failure of fusion of embryonic processes
Neural Tube Defects	— ectopic neural masses
Craniosynostosis	— premature fusion of cranial sutures
Atrophy/Hypoplasia	— under-development
Hypertrophy/Hyperplasia	— over-development
Neoplasia	— new and abnormal tissue growth
Post-Traumatic Deformity	— severe deformities following trauma
Unclassified	— unusual deformities awaiting diagnosis

Table 1: Summary of craniofacial anomalies (After Whitaker et al, 1981).

Alternatively, the so-called "Striped Y" classification (Kernahan, 1971) and its modifications (Friedman et al, 1991) have found favour with many surgeons and orthodontists in symbolically representing cleft lip and/or palate (Figs. 2, 3).

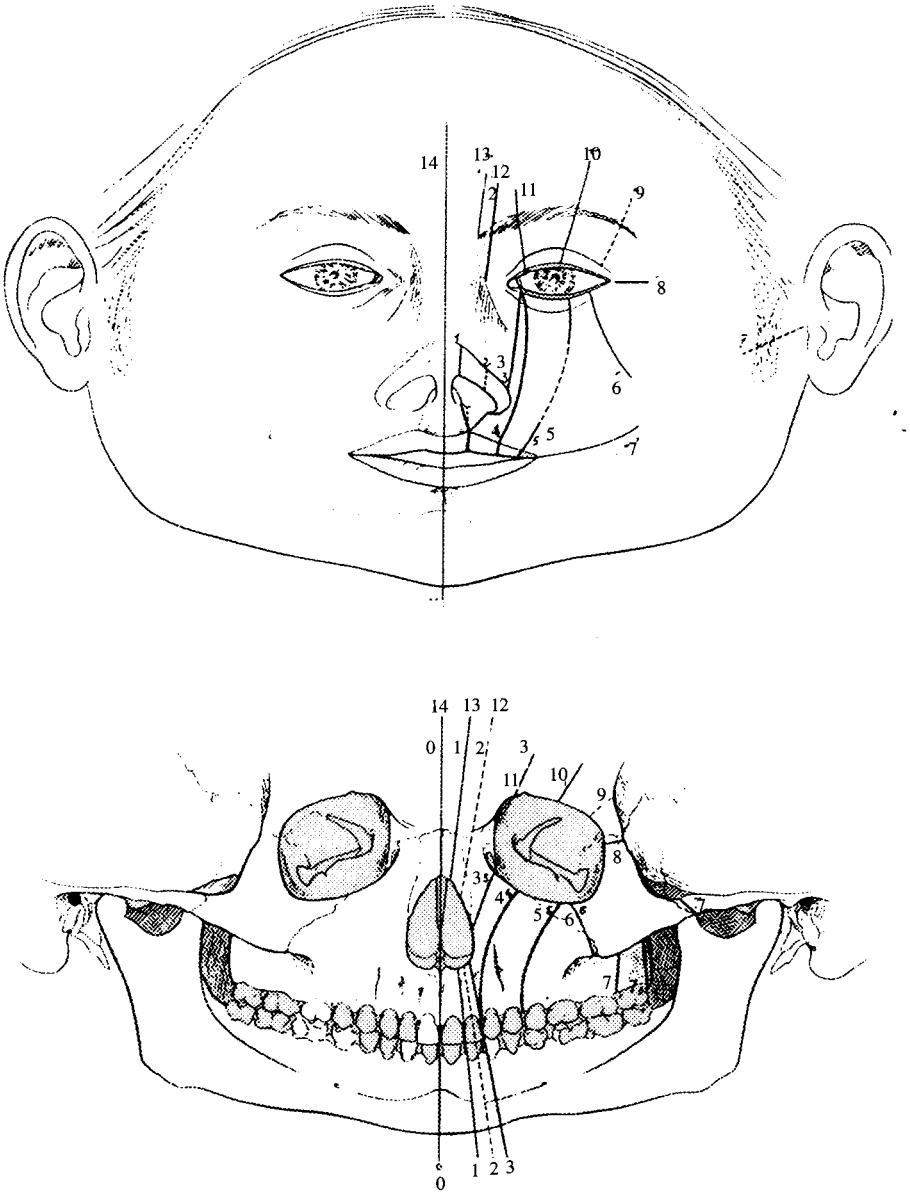


Fig 1: Tessier's craniofacial cleft classification (Tessier, 1976). The numbers represent the fifteen locations for clefts using the orbit as the point of reference.

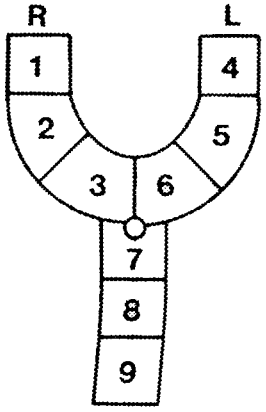


Fig 2: "Striped Y" classification (Kernahan, 1971). The incisive foramen is represented by the circle. Anterior to the incisive foramen, segments 1 and 4 represent the lip, segments 2 and 5 represent the alveolus, segments 3 and 6 represent the hard palate anterior to the incisive foramen. Posterior to the incisive foramen, the hard and soft palates are represented by segments 7,8 and 9.

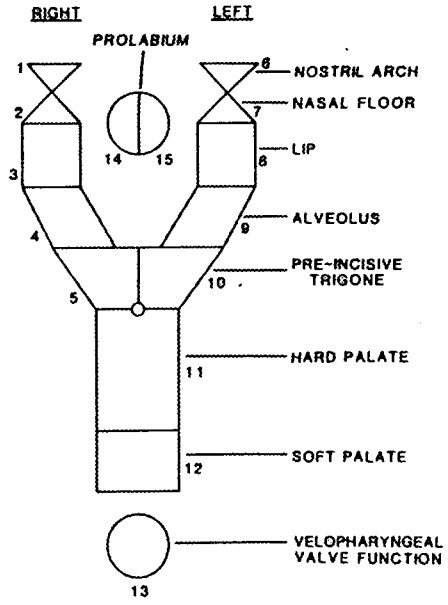


Fig 3: "Striped Y" modification (Friedman et al, 1991)

The most common craniofacial clefts are those of the lip and/or palate. Clinically, there is great variability in the appearance of clefts of the lip and palate ranging from the minor bifid uvula to the complete bilateral cleft lip and palate. For practical purposes, orofacial clefts can be classified simply by the location of the cleft and its degree of severity or extent. Table 2 shows a simplified descriptive classification system, which may be used to describe the many possible combinations of location and extent of orofacial clefts. For example, a cleft which involves the entire lip and alveolus on the left side, and extending posteriorly to include both the hard and soft palates, may be described as a "complete unilateral (left) cleft lip, alveolus and palate". Examples of the common cleft types are shown in Fig. 4.

Location of Orofacial Cleft	Degree of Severity / Extent
Lip Alveolus Palate Unilateral (right or left) Bilateral Median (rare) Oblique (rare)	Complete Incomplete Minimal - microform cleft lip - submucous cleft palate

Table 2: A simplified descriptive classification of orofacial clefts. The description will provide information on both the location and the extent of the cleft, and may involve many possible combinations.

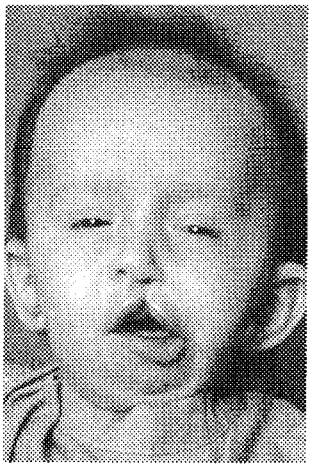
PRINCIPLES OF CLEFT LIP AND PALATE MANAGEMENT

Since hearing, speech, facial appearance, dental aesthetics and masticatory function are affected by the CLP condition, it is not surprising that a child with CLP has a long association with the cleft palate team, especially with the orthodontist.

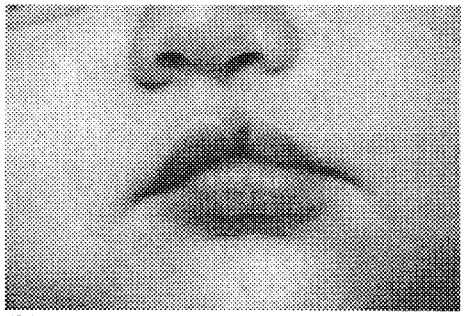
It is the underlying philosophy of treatment and the available resources that determine the treatment protocols employed by the various cleft palate centres around the world. Some centres promote early surgery on the lip and palate possibly to the detriment of growth, believing the establishment of normal function (e.g. hearing, speech) takes priority over possible growth disruption. Other centres, however, place greater emphasis on growth and therefore delay certain surgical interventions (e.g. hard palate repair until the early teens) to minimise scarring and hopefully allow full maxillary growth to be expressed. Most centres adopt an approach somewhere between these two extremes.

At the Children's Oral Health Service, the management of children with CLP is guided by three key principles:

- Firstly, a multidisciplinary team approach is the only approach which allows for the goal of optimal care to be provided for patients with CLP;
- Secondly, the child with cleft lip and/or palate should have established functional velopharyngeal, oral, and auditory anatomical structures in time for normal development and function to occur and this dictates to a large extent the timing for both surgery and orthodontic treatment;
- Thirdly, staged orthodontic treatment produces optimal orthodontic results for children with CLP. Patients and parents need breaks from active orthodontic treatment. It is too easy for treatment procedures to extend over many years leading to patient and parent burnout. On the other hand, the neglected child with CLP invariably will develop a severe malocclusion which becomes more difficult to resolve as an adult (Fig. 5).



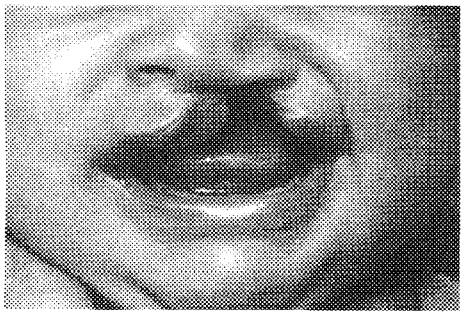
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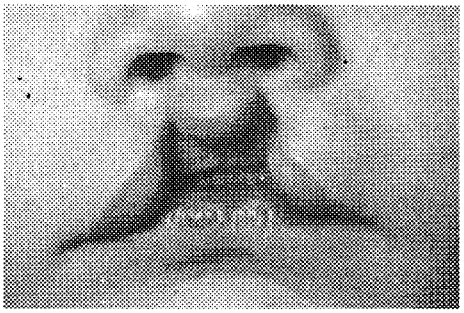
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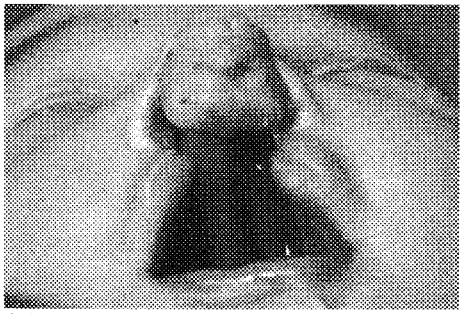
(d)



(e)



(f)



(g)

Fig 4: (a) Craniofacial syndrome involving clefting (Goldenhar Syndrome). Incomplete unilateral (left) cleft, hemifacial microsomia and microstomia (b) microform (left) cleft lip (c) incomplete unilateral (right) cleft lip (d,e) complete unilateral (left) cleft lip and palate (f) incomplete bilateral cleft lip (g) complete bilateral cleft lip and palate.

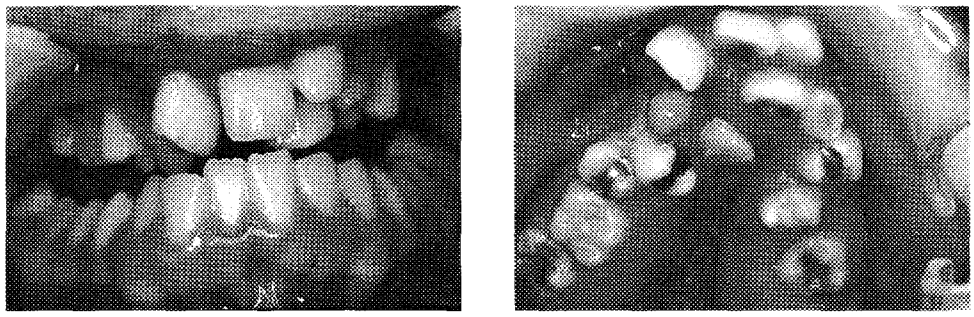


Fig 5: Severe malocclusion in an adult patient with cleft lip and palate having no follow-up dental treatment since the lip and palate repair.

With these principles in mind, the following priorities of the cleft palate team (in order from highest priority to lowest priority) are critical in the management of children with cleft lip and palate:

1 Hearing — which is of critical importance during the first six years of life for speech development and learning

2 Speech — most importantly the function of the velopharyngeal sphincter

3 Facial appearance — particularly from the second year of schooling for peer acceptance and psychological development

4 Dental function and aesthetics

The following overview amalgamates the main treatment procedures provided by the cleft palate team at the Children's Oral Health Service in chronological order from birth to adulthood. Orthodontic and surgical implications will be discussed briefly to reflect the beneficial and deleterious effects of CLP treatment.

INFANCY

Pre-lip repair

Early referral by the plastic surgeon of new-born infants with complete bilateral or very wide unilateral CLP to the orthodontist occurs during the first week after birth for the commencement of pre-surgical oral orthopaedics (PSO). Intraoral impressions are taken under general anaesthesia (for safety reasons) during the first week after birth for the construction of the pre-maxillary cap and an intra-oral appliance (Fig. 6). Minor surgery, such as the extraction of neonatal teeth (Fig. 7) and the release of Simonart's Band, is performed if required. It is considered that the orthopaedic re-alignment of the pre-maxilla (Fig. 8) and the bilateral segments prior to lip repair enables the plastic surgeon to more easily perform primary lip repair, resulting in less pressure on the sutures, a better facial profile, and a better maxillary dental arch than in non-PSO cases.

Lip repair

Lip repair occurs between the ages 3-6 months. The scarring, produced by surgery, results in a slightly smaller than normal oral commissure which places pressure on the maxilla (Figs. 9 and 10). Pre-surgical intraoral alginate impressions are taken at this time to provide a record of the maxillary arch shape for future reference. Grommets are inserted by the ENT surgeon, if required, under the same general anaesthetic session.

Palate repair

The optimal time for palate repair is 9-12 months of age, before speech develops. An alginate impression is taken under general anaesthesia for records immediately prior to the palate repair. Early closure of the palate is essential for normal speech development.

The main objectives of cleft palate closure are to:

1 facilitate the development of intelligible speech by providing a properly functioning velopharyngeal sphincter

2 minimise the deleterious effects on the abnormal maxillary dental arch form.

The trauma, soft tissue tension and long term contraction of the maturing scar tissue associated with cleft palate repair have a significant effect on long-term growth of the maxilla. Insufficient growth in transverse width of the maxilla may result in crossbites. In addition, scar tissue from the trauma of surgery has been blamed for the rotation of the upper central incisors in the direction of the cleft in unilateral patients with CLP. In patients with bilateral CLP, the upper central incisors may be tipped palatally as well as rotated. Modern surgery now produces better palate repairs, better maxillary growth and better speech.

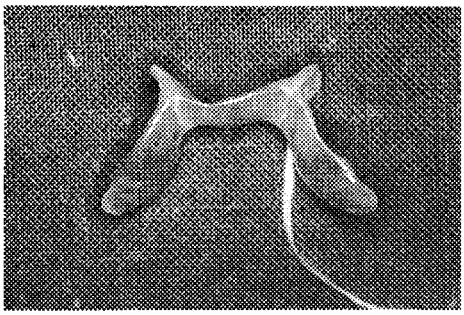




Fig 6: Intra-oral appliance used to prevent collapse of the bilateral cleft segments during pre-surgical oral orthopaedics.



Fig 7: Neonatal tooth erupted on the pre-maxilla.

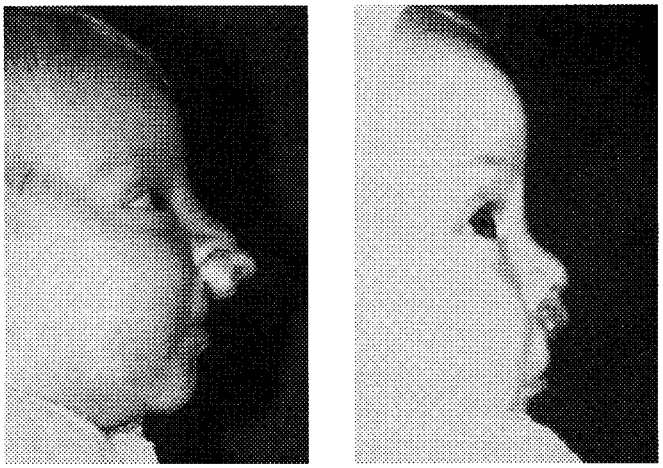
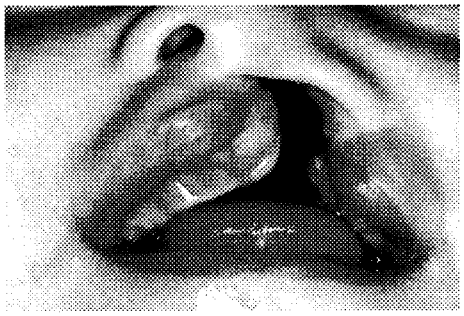
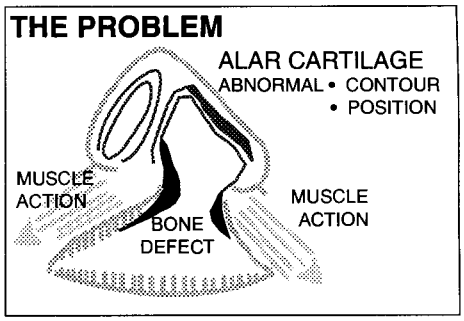


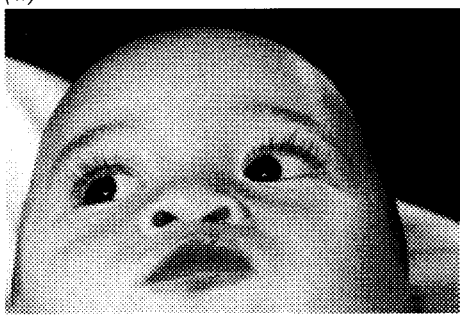
Fig 8: Pre- and post-surgical oral orthopaedic treatment.



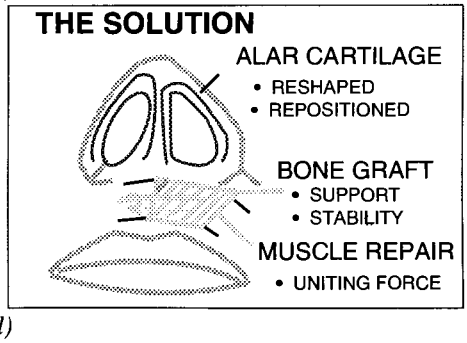
(a)



(b)

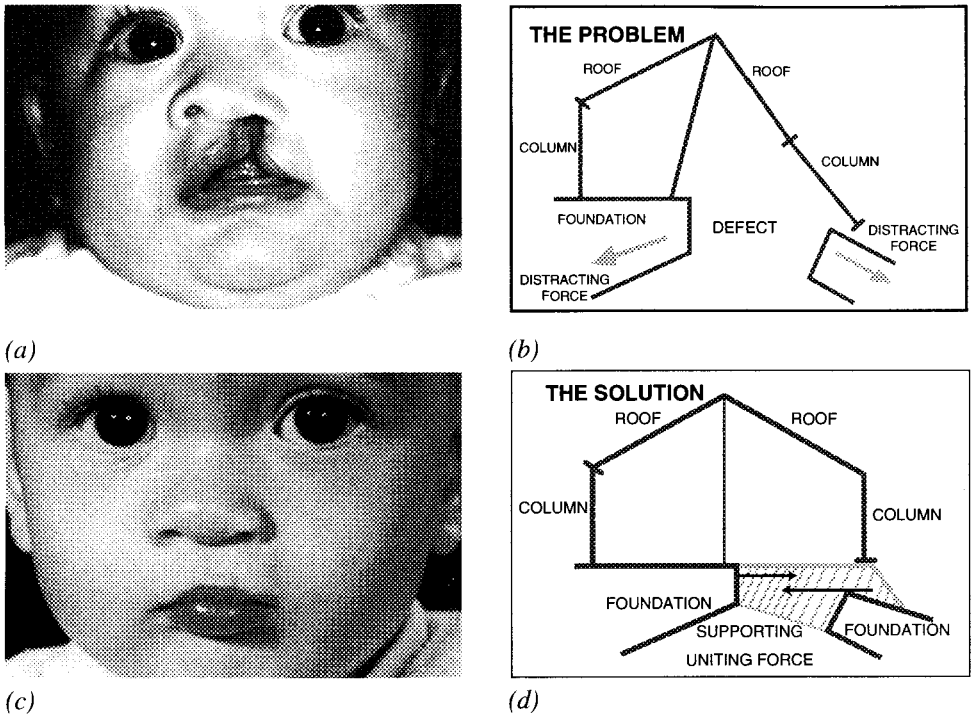


(c)



(d)

Fig 9: (a) Complete unilateral (left) cleft lip and palate at age 3 months (b) descriptive illustration of the problem (c) post-surgical appearance at age 6 months (d) descriptive illustration of solution to the problem (Courtesy of Dr M Lanigan).



(a) *(b)*

(c) *(d)*

Fig 10: (a, b) Pre-surgical facial appearance at age 3 months with illustration of the problem (c, d) post-surgical facial appearance at age 6 months with illustration of the solution to the problem – a primary bone graft was performed in this infant (Courtesy of Dr M Lanigan).

DECIDUOUS DENTITION

This period is generally a surgery free phase. Some procedures which may be performed during this period include the re-insertion of grommets, lip revision, pharyngoplasty and extraction of neonatal, malpositioned or supernumerary teeth. Construction of an obturator may be recommended by the speech pathologist to cover any residual palatal fistula if speech is affected by the nasal escape of air (normally undertaken after eruption of deciduous second molars). Traumatic crossbites of upper anterior teeth may be corrected with an upper removable appliance during this phase.

EARLY MIXED DENTITION (Age 7.5—8.5 years)

As maturing scar tissue impedes normal growth and development of the maxilla, expansion and re-alignment of the maxillary dental arch are performed during this time (Fig. 11). Extraction of retained deciduous anterior teeth, frenectomy and/or gingivoplasty may be required. The objectives of early mixed dentition treatment are to:

1 laterally expand and anteriorly protract the constricted maxillary arch so that the alveolar segments are optimally aligned prior to bone grafting of the alveolar

defect

2 correct malalignment of individual teeth to enable the roots to complete their development in their de-rotated positions

3 correct crossbites (anterior and posterior)

4 open space for the normal eruption of permanent teeth

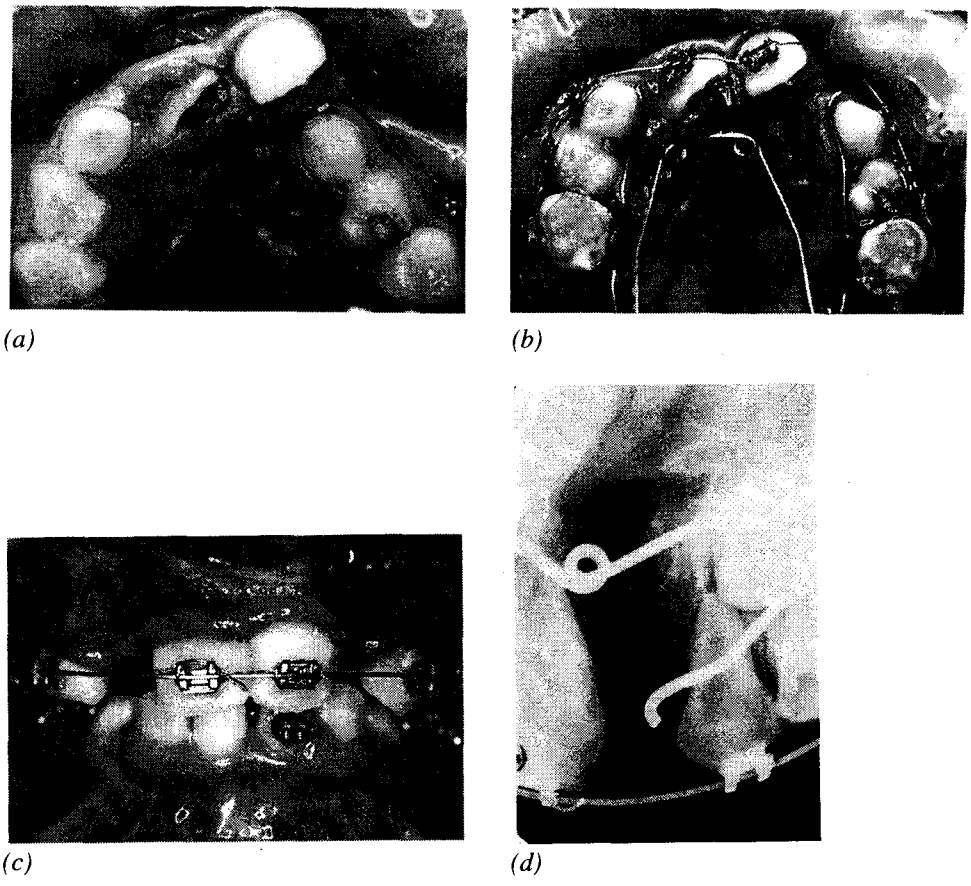
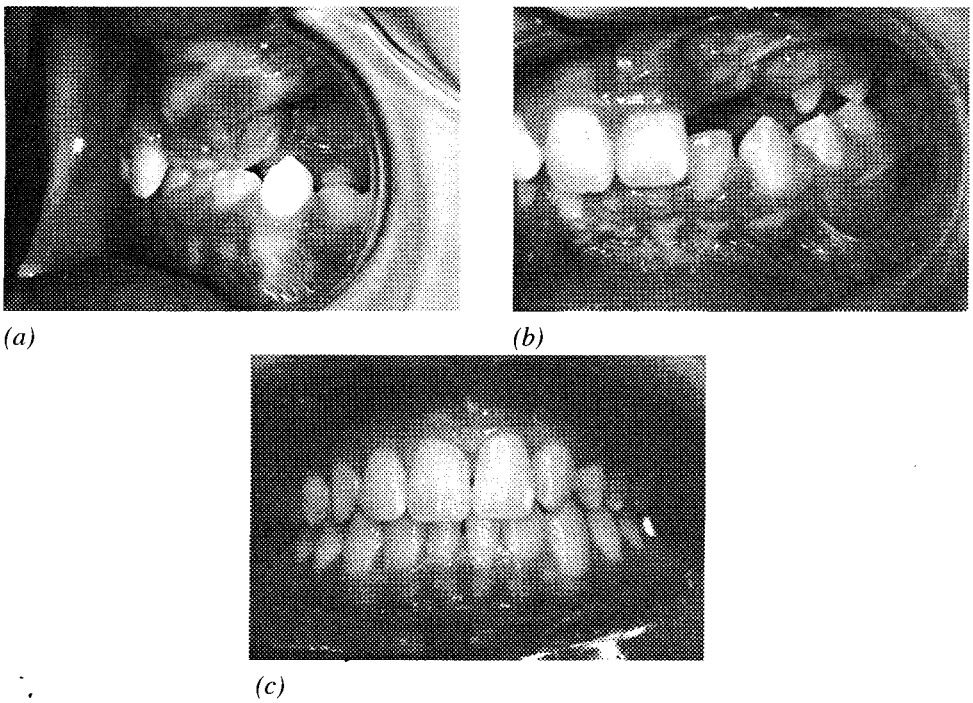


Fig 11: (a) Early mixed dentition stage of complete unilateral (left) cleft lip and palate with collapsed segment on the left side (b, c) expansion completed with a quadhelix and alignment of teeth with fixed appliances (d) radiograph showing the alveolar cleft defect following expansion.

Orthodontic intervention at this stage has significant psychosocial benefits for the child through improvement in dental appearance and dentally related speech. Once these objectives have been achieved, active orthodontic appliances are removed. The retention of the expanded maxilla is critical, particularly during the pre-bone graft and post-bone graft stages.

LATE MIXED DENTITION (Age 9-11 years)

The late mixed dentition is generally a non-active phase of treatment. Active orthodontic treatment at this stage becomes difficult, since deciduous buccal segments may become mobile and exfoliate. Bone grafting of the alveolar cleft defect and the adjacent nostril base is performed by the plastic surgeon during this stage when the permanent canine on the cleft side displays approximately half root formation. Cancellous bone harvested from the iliac crest, acts as a matrix for the induction of new bone. The erupting canine stimulates new bone formation as it brings its supporting apparatus with it. The grafted bone is replaced as the bone grafted cleft is re-modelled and new bone is formed. Bone grafting enables orthodontic space closure to be performed into an area which was once a bony defect (Fig. 12). It is important to note that bone is placed only in the region of the alveolus, not in the defect of the hard palate. Hence, bone grafting is not performed in cases of isolated cleft palate.



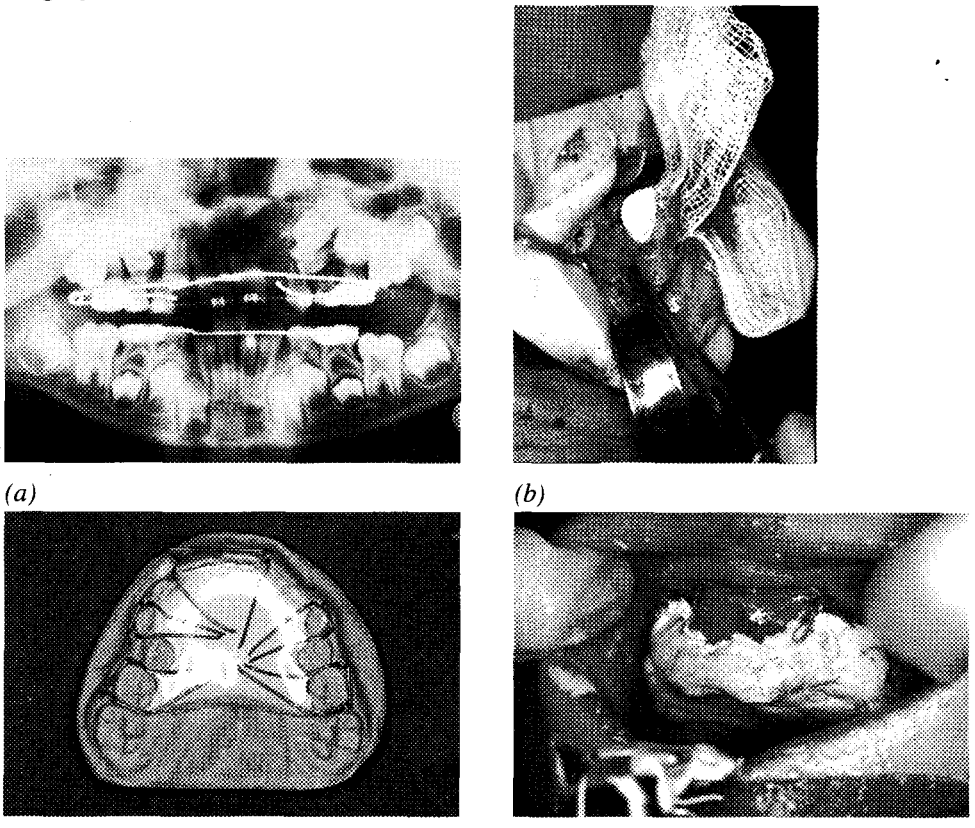
(a) *(b)* *(c)*

Fig 12: (a) Complete unilateral (left) cleft lip and palate pre-bone graft (b) occlusion post-expansion and post-bone graft (c) occlusion post-orthodontic treatment – a good result was achieved with the upper left canine substituting for the missing lateral incisor.

It is therefore essential that the orthodontist and the plastic surgeon plan and coincide the bone graft with the imminent eruption of the canine. Bone grafts will survive only if stressed correctly. In the maxilla, the stresses are induced by a tooth erupting through and functioning within the graft. If a tooth does not erupt through the graft within 12-24 months, the graft will partly or completely resorb. If the bone grafting

procedure is delayed until after the eruption of the canine, the graft may not be as successful because it is difficult to induce new bone formation along the side of an existing tooth.

This surgical procedure may also include extraction of retained deciduous teeth adjacent to the cleft, removal of supernumerary or malformed teeth or a gingivoplasty during the same general anaesthetic session. A maxillary surgical splint with Coe-Pak® dressing is inserted by the orthodontist immediately following the bone graft procedure (Fig. 13). This surgical splint is left undisturbed for two weeks following surgery.



(a) *(b)*

(c) *(d)*

Fig 13: (a) OPG showing unerupted upper left permanent canine close to half root formation, nearing ideal time for alveolar and nostril base bone graft (b) cancellous bone from the iliac crest is placed into the alveolar cleft (c) maxillary surgical splint ready for insertion immediately following the bone graft (d) insertion of maxillary surgical splint lined with Coe-Pak® dressing to protect the bone-grafted area.

The surgical splint serves several functions:

1 to prevent collapse of the expanded maxillary arch

2 to prevent exchange of pressures between the nasal and oral cavities

® Coe-Pak, GC, America

3 to improve patient comfort following bone grafting surgery

4 to protect the wound from forces of mastication and deglutition during the healing phase

5 to reduce the number of sutures placed during surgery, producing a better blood supply with less venous congestion and to minimise the number of foreign bodies in the healing surgical site.

Cleaning and irrigation of the maxillary arch and the maxillary surgical splint occurs two weeks after the bone graft at which time healing is usually progressing well. The Coe-Pak® lining would be likely to encourage growth of anaerobic organisms. However, clinical experience has found this not to be a problem although further investigation is warranted. Appointments are then made for a new maxillary retainer to be constructed to continue retention of the expanded maxilla.

As it is the orthodontist who monitors the development of the dentition, it is also the orthodontist who usually advises the plastic surgeon on the timing of the bone graft. Once the date for the bone graft has been determined the construction of the maxillary surgical splint is undertaken two weeks before the bone graft. Failure in communication and co-ordination between the plastic surgeon and the orthodontist at the bone graft stage can have a detrimental effect on the expanded maxillary arch. If no notice is provided to the orthodontist for the construction of the maxillary surgical splint the expanded maxilla will significantly collapse in the post-operative period. The importance of maintaining the expansion pre- and post-operatively cannot be overemphasised.

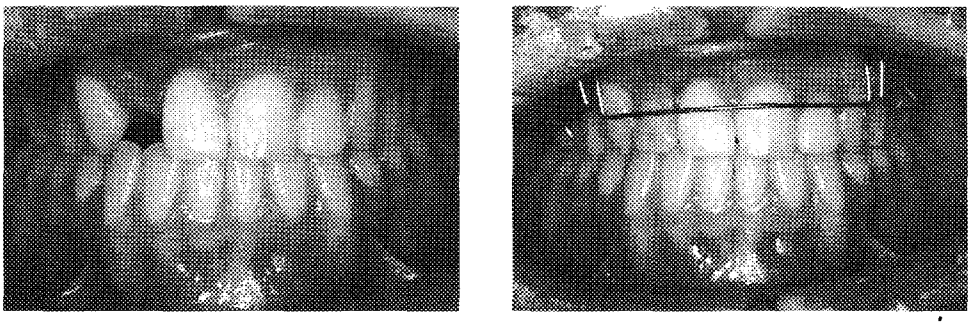
EARLY PERMANENT DENTITION (Age 12-14 years)

This is usually the final phase of fixed appliance orthodontic treatment for most children with CLP. A decision must be made if orthodontic treatment alone will result in a good facial profile and the correction of the malocclusion or if a combined surgical orthodontic approach is required when growth is completed to advance the maxilla. Retention after orthodontic treatment is completed is vital. Some retainers may incorporate an acrylic tooth or teeth if space closure was not possible (Fig. 14).

THE YOUNG ADULT (Age 15-18 years)

It is prudent to determine what the young adult really wants. Adjunctive treatment procedures such as a septorhinoplasty and or a genioplasty may be all that the young adult wishes. Most patients with CLP have a tendency towards a Class III malocclusion as a result of deficient anteroposterior and vertical maxillary growth. A mild growth deficiency may be alleviated by orthodontic treatment alone. However, if the deficiency is severe, orthognathic surgery will be required at this time when growth is completed. Speech should be thoroughly evaluated before and

after orthognathic surgery. The speech pathologist may recommend a post-osteotomy pharyngoplasty if speech is affected.



(a) (b)

Fig 14: (a) Orthodontic treatment completed in the permanent dentition stage for a child with complete unilateral (right) cleft lip and palate (b) upper removable retainer incorporating an acrylic tooth to replace a congenitally missing upper right lateral incisor.

SUMMARY

This overview provides a summary of CLP management. The importance of the team approach to management from the initial stages of growth and development from birth through to adulthood is emphasised. Through staged orthodontic care, patients with cleft lip and palate are provided with treatment at the most appropriate time with the aim of producing optimal results.

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GLOSSARY

Adenoid facies – facial morphology typified by incompetent lips, increased overjet, pinched nares and oro-nasal respiration.

Alastic or alastik – an elastic like material which is manufactured in a variety of formats including elastic thread, elastic chain and single small modules. These various forms may be used to close space, tie teeth to an arch wire or to ligate an archwire into edgewise brackets.

Alveolar/nostril base bone graft – grafting of cancellous bone into the region of the cleft to restore bony continuity of the alveolar ridge and to provide support to the nostril base on the cleft side.

Andresen appliance – a functional appliance characterised by its simple design consisting of an acrylic block which is fitted to both the upper and lower dental arches and causes the lower jaw to bite into a forward or working bite position. This stimulates the muscles of mastication to contract and exert a distal force on the upper dento-alveolar structures and a reciprocal mesial force on the lower dento-alveolar structures.

Anterior crossbite – lingual displacement of one or more of the six upper anterior teeth or labial displacement of one or more of the six lower anterior teeth beyond the incisal edges of the opposing teeth.

Anterior oral seal – the seal achieved during swallowing and respiration and occurring without muscular strain with competent lips. A seal may also be achieved by contraction of the lips or between the lips and tongue in cases of abnormal function.

Adams crib – a special retainer used almost universally on removable appliances and usually constructed from 0.7mm stainless steel wire. The original design was proposed by C P Adams.

Begg appliance – a fixed appliance system utilising the Begg bracket which is designed to allow free tipping of teeth attached to the arch wire. P R Begg was an Adelaide orthodontist whose theories of occlusion and treatment methods were widely accepted.

Bilateral segments – the lateral alveolar segments of the bilateral cleft palate including elements of the secondary palate.

Bionator – a functional appliance derived from the Andresen appliance which incorporates a palatal wire and a long sweeping labial wire to reduce the pressure of the lips against the teeth.

Bite plate (plane) – an acrylic platform which may be designed to occlude with the lower anterior teeth or the lower posterior teeth and whose main function is to disclude the teeth.

Bolton analysis – an analysis of tooth widths to determine whether the teeth in the upper and lower arches are correctly matched in their mesio-distal widths.

Braces – a term used by patients to indicate fixed appliances.

Brachyfacial – a term introduced by Ricketts and used to indicate a square broad facial skeletal structure with a low mandibular plane angle.

Bracket – a small slotted device which is either bonded to the tooth or welded to a band and enables an arch wire to be tied to the individual tooth.
Buccal crossbite (scissor bite) – relative buccal displacement of one or more upper posterior teeth so that the tooth is completely unopposed.

Buccal segment relation – the antero-posterior (sagittal) relationship of upper to lower posterior teeth. This is usually described as normal or full unit or half unit of displacement in the Class II or Class III direction.

Button – a small mushroom shaped attachment which is usually applied to the lingual surface of a tooth to permit the attachment of elastics.

Class I occlusion – normal mesio-distal relations of the first permanent molars.

Class II occlusion – distal relation of the lower arch to the upper arch with the lower first permanent molars lying beyond the cusp-to-cusp distal position. Division 1 – protruded upper incisors. Division 2 – retruded upper incisors

Class III occlusion – mesial relation of the lower arch to the upper arch with the lower first permanent molars lying beyond the cusp-to-cusp mesial position

Cleat – a small accessory device which is usually placed on the lingual surface of a tooth to permit the attachment of elastics.

CLP – cleft lip and palate.

Competent lips – lips which meet without muscular strain and with the mandible in the rest position.

Compensation – the natural process of tooth tipping which occurs in an attempt to compensate for a skeletal positional discrepancy between the upper and lower arches.

CO-CR displacement – when the position of maximum intercuspation (centric occlusion) is not coincident with the unstrained retruded contact position of the mandible.

Concave profile – where the chin is more prominent than the midface and forehead.

Convex profile – where the midface is more prominent than both the forehead and chin.

Decompensation – the process of reversing the natural compensation process. Decompensation is done prior to orthognathic surgery to permit the correct occlusion of the incisor teeth after the surgical movement is complete.

Diastema – a space between the upper or lower central incisors.

Distoclusion (disto-occlusion) – Class II occlusion or tendency.

Dolichofacial – a term introduced by Ricketts and used to indicate a facial skeletal structure with a high mandibular plane angle, long face and often a convex profile.

Edgewise appliance – a fixed appliance based on brackets with a rectangular slot which permits the placement of square or rectangular wires and therefore allows control of the tooth in all three dimensions. The bracket slot will also accept round wires.

Endogenous tongue thrust – a tongue thrust which is thought to be an inherited muscular pattern and therefore resistant to change.

Exposure – the process of surgically uncovering an unerupted tooth for the purpose of inducing its eruption.

Fibrectomy – a periodontal surgical operation which severs the supra-crestal fibres of the periodontal membrane in order to reduce the post-orthodontic relapse tendency of teeth which have been rotated.

Frankel appliance – a functional appliance constructed with a wire frame and acrylic shields and designed to induce dento-alveolar development.

Frenectomy – a periodontal surgical operation which dissects the soft tissue from between the central incisors in order to remove the dense fibrous band which may cause relapse after closure of the space.

Full unit – the full width of a bicuspid tooth.

Functional appliance – an appliance which depends on forces generated by muscles to move the teeth.

Genioplasty – reshaping to accentuate, reduce or modify the sub-apical mandibular symphysis for the purpose of altering the lower facial profile. This may be achieved by dissection and movement of the bony chin or by grafts of various materials.

Gingivoplasty – a surgical procedure designed to improve the gingival contour around anterior teeth adjacent to sites of previous surgical intervention.

Growth rotation – the process of rotation of the mandible as it grows. Anterior (closing) rotation involves lowering of the gonial angle relative to the symphysis while posterior (opening) rotation involves lowering of the symphysis relative to the gonial angle. Anterior rotation is expected in brachyfacial types and posterior rotation is expected in dolichofacial types.

Grommets – small tubes placed into incisions in the tympanic membrane to ensure equalisation of pressures between the middle and external ear.

Gummy smile – a smile which displays an excess of the mucosa above the upper anterior teeth.

Hawley appliance – a simple upper retainer which includes a labial bow and Adams cribs on the molars. It is the standard upper retaining appliance.

Headgear – an extraoral appliance which pulls from the neck or back of the head to produce movement of the teeth. It is usually attached to the upper first permanent molars.

Herbst appliance – a fixed functional appliance which is not removable by the patient.

Hook – a device usually attached to a molar band for the purpose of attaching elastics.

Imbrication – a term to indicate crowding of the incisors.

Incisor angulation – the sagittal angular positions of the upper and lower incisors usually assessed relative to the Frankfort and mandibular planes respectively.

Incisor reangulation – correction of the angulations of the upper and lower incisors to the normal values. The value of the overjet after correction is regarded as a true indicator of the maxillo-mandibular skeletal relationship.

Incompetent lips – lips which are apart at rest with the mandible in the rest position and which require muscular contraction to be closed.

Intermaxillary elastics – elastics from the upper to lower teeth. They may be Class II or Class III elastics.

Keys of occlusion – indicators of normal occlusion as originally proposed by Andrews.

Lingual crossbite – relative lingual displacement of one or more posterior teeth so that the upper buccal cusps occlude inside the lower buccal cusps.

Lip bumper – a device constructed from a heavy wire and a plastic overlay. The bumper sits in the lower labial sulcus and stimulates the lips to exert a pressure on the molars which are moved distally.

Lip revision – a secondary surgical procedure undertaken at some stage subsequent to primary lip repair to improve the aesthetics and/or function of the lip.

Lip trap – the lip relationship commonly seen with an increased overjet where the lower lip lies mainly behind the upper incisors with the upper incisal edges resting into the lower lip. There is commonly a deep supra-mental groove in the lower lip. The condition is often associated with a retroposition of the lower incisors.

Leeway space – the difference in the sum of the mesiodistal widths of the deciduous molars plus the deciduous canine and the sum of the mesiodistal widths of the two bicuspids plus the canine on the same side of the arch.

LeFort I – a surgical operation which detaches the maxilla from the structures to which it is attached. The line of the cut is made above the apices of the teeth. The maxilla may then be repositioned as required.

Mandibular displacement – any lateral or anterior displacement of the mandible on closure from the retruded contact position to centric occlusion due to cuspal interference.

Mesofacial – a term introduced by Ricketts and used to indicate a facial skeletal structure within normal limits.

Mesioclusion – Class III occlusion or tendency.

Mixed dentition analysis – measurement of the spacing or crowding in the arches anterior to the first permanent molars in the mixed dentition stage. This requires an estimate of the mesio-distal widths of any unerupted canines and bicuspids.

Molar relation – the mesio-distal relation of the mesio-buccal cusp of the upper first molars relative to the lower first molar. It may be Class I, II or III.

Molar tube – a tube soldered to a molar band and into which the distal end on an archwire slides.

Monobloc – a term used to describe the Andresen functional appliance and indicating its construction as a single piece of acrylic.

Natal and neonatal teeth – deciduous or supernumerary teeth present at or erupting soon after birth.

Neckstrap – the elastic portion of a cervical headgear assembly.

Neurocranium – that portion of the bony skull accommodating the brain and eyes.

Normal occlusion – an occlusion which functions comfortably, has an acceptable appearance, does not require undue maintenance and does not jeopardise oral health

Obturator – a maxillary acrylic removable appliance designed to seal a residual oronasal fistula orally, thus preventing or minimising escape of air, fluids or food into the nasal cavity.

Oral screen – a simple functional appliance which fits into the upper and lower labial sulcus forming an acrylic shield outside the upper and lower teeth.

Orthognathic surgery – surgery of the upper or lower jaws which is performed to alter the positions and relationships of the jaws.

Osteotomy – an operation involving the division or splitting of a bone without significant bone removal.

Overbite – the vertical relation of the upper and lower incisors.

Overjet – the sagittal relation of the upper and lower incisors.

Palatal (oronasal) fistula – a patent, epithelial-lined communication between the oral and nasal cavities. Generally used to describe residual defects subsequent to palatal surgical repair.

Pericision – see fibrectomy.

Pharyngoplasty – a surgical procedure used to produce satisfactory function of the velopharyngeal sphincter, improving the length or function of the soft palate.

Pin – a brass attaching device for use with Begg brackets.

Posterior oral seal – the seal achieved between the base of the tongue and the underside of the soft palate but broken in patients who breathe through the mouth.

Prediction table – a table of the predicted widths of unerupted canines and bicuspids based on the width of the lower incisors. The method of Moyers is commonly used.

Premaxilla – the tissues comprising the portion of the palate anterior to the incisive foramen and including the alveolus and the incisor teeth. Term usually reserved for bilateral clefts.

Presurgical orthopedics – movement of the displaced fragments which form the lip and alveolus in the newborn cleft lip and palate baby. The fragments are moved to normal positions prior to corrective surgery to close the cleft.

Primary lip repair – a surgical procedure, commonly undertaken at three to six months of age, which achieves complete closure of the soft tissues of the lip and/or anterior alveolus.

Primate space – the natural mixed dentition space distal to the upper deciduous canine and mesial to the lower deciduous canine.

Proclination – abnormal forward angulation of the incisors usually due to tipping.

Prognathic – jaw relation with a prominent lower jaw

Prolabium (pre-surgery) – in bilateral clefting, the midline portion of the upper lip which, together with the premaxilla, is formed from the fused embryological medial nasal processes.

Prolabium (post-surgery) – becomes the central part of the upper lip.

Rapid maxillary expansion – expansion of the maxillary arch with separation of the midline palatal suture.

RME – rapid maxillary expansion usually achieved with a fixed palatal expansion device.

Retention – the process of holding the post-orthodontic positions of the teeth to allow settling and consolidation of the occlusion.

Retroclination – abnormal backward angulation of the incisors usually due to tipping.

Retrognathic – jaw relation with a receding lower jaw

Rigid fixation – fixation of the bony segments of an osteotomy using plates and/or screws. The system has the advantage of allowing early post-surgical function of the mandible.

Sagittal split – an osteotomy in which buccal and lingual cortical plates of the ramus are separated.

Screw appliance – any appliance incorporating an expansion screw.

Sectional arch – a fixed appliance attached to a section of an arch rather than all the teeth in an arch.

Septorhinoplasty – a surgical procedure designed to improve nasal contour and airways.

Serial extraction – the process of extraction commencing with the deciduous canines followed by the deciduous first molars and finally the first bicuspids in order to alleviate crowding and to minimise appliance treatment.

Simonart's band – a small band of soft tissue, present at birth, bridging an otherwise complete cleft of the alveolus. It is not part of the lip and is not to be confused with an incomplete cleft of the lip.

Skeletal pattern or relationship – the sagittal relationship between the upper and lower jaws.

Soft tissue pattern – the shape and functional pattern of the circumoral soft tissues and tongue.

Straight profile – where the forehead, midface and chin are equally prominent

Submucous cleft palate – a defect in muscle union across the soft palate, but with an intact mucosal surface. May clinically present with bifid uvula, a notched posterior border of the hard palate, and hypernasal speech.

Sunday bite – a forward bite adopted by the patient to compensate for an increased overjet giving a false normal appearance.

Teuscher appliance – a functional appliance with torquing spurs to the upper incisors and usually incorporating a headgear.

Tongue thrust – forward or lateral displacement of the tongue between the teeth.

Torque – the process of moving the apex of a tooth while holding the crown.

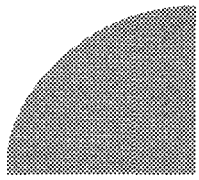
Twin block – a functional appliance made in separate upper and lower parts.

Ugly duckling stage – that temporary stage of dental development where the erupting canines press against the distal root surfaces of the lateral incisors causing their crowns to tilt distally away from the central incisor crowns.

Velopharyngeal sphincter – those anatomical structures comprising the soft palate and the lateral and posterior pharyngeal walls which function to selectively seal the nasopharynx from the oropharynx during speech and eating.

Viscerocranium – that part of the bony skull associated with mastication, respiration and speech – that part not accommodating the brain or eyes.

Wits analysis – an analysis of the relative antero-posterior relationship of the upper and lower skeletal bases. It is calculated as the difference between projections of A point and B point onto the occlusal plane and may be positive or negative.



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